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THE SIXTY-INCH REFLECTOR OF THE MT. WILSON SOLAR OBSERVATORY.

E. A. FATH

FOR POPULAR ASTRONOMY.

The new sixty-inch reflecting telescope of the Mt. Wilson Solar Observatory has been in operation for about one year. It may therefore be of interest to readers of POPULAR ASTRONOMY to have a brief description of the instrument and to know what work is being carried on with it.

The telescope is primarily a reflector of the Newtonian type with an aperture of sixty inches and a focal length of twenty-five feet. The outer section of the tube carrying the Newtonian plane mirror can be replaced by similar sections carrying convex mirrors which reflect the cone of light back toward the large mirror. Then by introducing a plane mirror in the path of the beam near the lower end of the tube to throw the beam out to the side it is possible to obtain equivalent focal lengths of 80, 100 or 150 feet. For direct photography either the 25- or 100-foot focus is used; for spectrographic work the 25-, 80- or 150-foot combinations are available.

The steel tube is of skeleton construction, exceedingly rigid and weighs only four tons. It is carried by a massive fork at the upper end of the polar axis. Most of the weight is taken off the bearings of this axis by means of an iron float fastened to it and buoyed up by mercury. The moving parts of the telescope weigh about twenty-three tons.

The driving clock, which stands six feet high, is of the Warner and Swasey type such as is used for the Yerkes and Lick refractors. There is, however, one important modification. Instead of the governor being connected with the driving shaft by means of the ordinary system of gears it is connected directly through a small worm gear. The weight for the clock consists of sixteen cast iron disks, each weighing about one hundred pounds. The winding of the clock is automatic. When the weight is nearly down, it closes a circuit and an electric motor then winds it up.

When the weight has reached the proper height, it breaks the motor circuit. The clock thus needs no attention throughout the night. The large worm gear which rotates the telescope is ten feet in diameter. When properly rated the clock runs very accurately. Frequently the guiding star will remain on the cross-wires of the guiding eyepiece for five minutes at a time.

The optical properties of the large mirror are of the highest order. The surface is correct to about 0.000002 of an inch. This is 1/10 the wave length of sodium light. Under good atmospheric conditions star images measuring only 1″.3 in diameter have been obtained on Seed "23" plates with exposures up to two hours in length.

The building and dome are built of steel throughout and rest on a concrete foundation. The walls are double with an air space of two feet between them and so arranged as to permit a free circulation of air. The dome, which is fifty-eight feet in diameter, is covered, except in winter, with a cover of white canvas about two feet above the metal surface. It is found that in the summer this simple device to prevent the Sun shining directly on the dome cuts in two the daily range of temperature within.

The building has two floors, the lower at the ground level and the other, the operating floor, nineteen feet above this. The former is of cement and the latter of thin steel plates. The opening in the dome is sixteen feet wide, the shutter running back over the dome instead of opening to the side as in the usual type. The observing at the primary focus is done from a movable platform that can be raised or lowered along the curve of the dome opening. Electric motors are used for all movements of the telescope, dome and observing platform.

The changes of temperature referred to above have an appreciable effect on the performance of the telescope owing to the changes in the focal setting as the tube cools during the night. With the canvas cover over the dome this amounted to only 0.04 of an inch during the average night. This, however, was still too great, especially for long exposures running over several hours. In order to further decrease the effect an insulating chamber of woolen blankets was made to be placed over the lower half of the tube, the mirror, the float, etc. Radiation from the floor is prevented by mats of the same material. The opening in the tube where the covering surrounds it is closed by a tight fitting wooden cover lined with felt. Under average conditions the daily range of temperature within the cover has

PLATE III.

60-INCH REFLECTOR MOUNTING IN DOME.

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PLATE VI.

ULTRA-VIOLET LIGHT PHOTOGRAPHS.
By R. W. Wood.

Photographs of landscapes made by the ultra-violet do not differ very greatly from ordinary photographs except in the curious circumstance that objects standing in full sunlight cast no shadows. The ultra-violet light comes almost entirely from the sky, the illumination being not unlike that which obtains in a fog. A number of interesting pictures made in this way will be found in the article already alluded to. A description of them in the present paper would be out of place. It was found in the course of the experiments that many substances, white in ordinary light, were quite black when photographed by the ultra-violet rays. This was true of white garden flowers, and in an especially marked degree in the case of Chinese white paint (zinc oxide). On Plate VI will be found reproduced two photographs of the page of a magazine on which are painted some words with this pigment. The upper picture was made with an ordinary lens of glass, the lower with the quartz-silver combination. It will be observed that in ultra-violet light the Chinese white is much blacker than the printer's ink.

While painting the words I inadvertently omitted one letter in the word appears. The mistake was rectified by carefully erasing the last three letters with a brush and clean water, drying the paper and painting the letters anew. So far as I could see I removed every trace of the white pigment, and no trace of the correction appears in the photograph made by visible light. The one made by ultra-violet, however, shows a very conspicuous smutch, which shows us how sensitive these rays may be in detecting slight traces of substances which absorb them. These two pictures are given to illustrate the principle of the method as applied to selenography, and it is clear that a slight but extensive deposit of zinc oxide on the Moon's surface which was quite invisible and which could not be photographed by ordinary means, might be clearly brought out in a photograph taken through a silver film with a quartz lens.

The first experiments in lunar photography were made with a quartz plano-convex lens of a little less than two meters focal length. The lens was made so that its focal length for the ultra-violet rays utilized should be as nearly as possible the same as that of my 12 cm- refractor for yellow light. My plan was to superpose a negative made by ultra-violet and a positive made by yellow light. Uniform density would then result except at spots differentiated by the two sorts of rays utilized. This will be recognized as an adaptation of the principle used by Professor Pickering for detecting variable stars.

It was found that with a silver film of the requisite density, an exposure of about two minutes was necessary. This necessitated an arrangement for pretty accurate following, and as I had no clock driven telescope I improvised an equatorial mounting for the telescope out of an old bicycle frame. The wheels were removed and the frame stood up in a wooden box in such a position that the steering axis pointed at approximately the latitude angle of East Hampton. The box was then filled with Portland cement which was allowed to solidify. The box was then knocked to pieces, and the frame was left imbedded in a massive block of artificial stone. This was mounted on a small brick pier and one end blocked up until the steering axis pointed at the pole. The twin telescopes were mounted on a declination axis fastened to a piece of wooden joist attached to the handle bars. Slow motion was communicated by means of a brass screw of small pitch, supported on a rod attached to the T-tube which originally held the saddle, and the telescope was elevated or depressed by an iron rod, clamped to the end of the saddle which carried the telescopes, and passed down through a block of wood attached to the front forks. A fuller description of the arrangement will be found in the *Scientific American* for October 23 and in a recent number of the *English Mechanic*.

Cramer Isochromatic plates were used. Exposures were made with the quartz telescope using the other telescope with its cross hairs as a guiding telescope, and also with the visual telescope through a bichromate of potash screen. In the latter case the time of exposure was less than half a second and no attempt was made to follow.

The plates were developed in hydrochinon, and a very large number were exposed with different times of exposure and different lengths of development. It was found that the plates made with the ultra-violet screen showed much less contrast, and on all there is a trace of an area bordering the crater Aristarchus which is dark in only ultra-violet light. The size of the image was too small, however, to make the results very satisfactory, and having demonstrated the feasibility of the method, the experiments were discontinued until my return to Baltimore. Early in October I assembed apparatus for obtaining pictures on a larger scale. It seemed best to use a reflector rather than a quartz lens of longer focus for obvious reasons. A silver on glass instrument would not be very efficient, since silver reflects only about four per cent of the rays with which we are concerned.

PLATE VII.

LUNAR PHOTOGRAPHIC TELESCOPE.

Made by R. W. Wood.

A 15 cm. concave mirror of speculum metal about 3.5 meters focus was mounted at the eye end of the ten-inch refractor of the University, and the plate holder fastened to the other end of the tube near the object glass. The plate was 7 cms. to one side of the axis of the mirror, but the definition was nearly perfect. The long focus quartz lens with its silver film was mounted about 5 cms. in front of the plate to serve as a ray filter.

Photographs taken with this apparatus showed clearly the existence of an extensive deposit to one side of Aristarchus which did not appear in any of the pictures made with the yellow screen. The deposit is shaped much like a figure 3. Three pairs of the photographs are reproduced on Plate VII, taken on three different dates. As is clear from these pictures little or no trace of the deposit is shown by yellow light. I have tried photographing it with a nitroso screen, which transmits a region of ultra-violet slightly less refrangible ($\lambda = 3400 - 3700$) than that passed by the silver film, and find that this deposit appears, but that it is not nearly as distinct as with the shorter radiations.

In the case of the pictures made in Baltimore I find that the contrast between the gray plains and the bright areas is about the same in the two cases, and I am at a loss for an explanation of this, for with the East Hampton apparatus this was never the case.

The fact that the bright craters are quite as bright with the ultra-violet light enables us at once to say what the strongly reflecting material is *not*, for I have found out that zinc oxide sulphur and certain other light colored substances are quite black in ultra-violet light. As to the nature of the dark deposit around Aristarchus further experiments will be necessary before we can begin to guess. By a process of elimination we shall doubtless be able to exclude a large number of substances, narrowing the thing down still further by measuring its reflecting power for different regions of the ultra-violet and visible spectrum. Infra-red pictures will also help in all probability. I have already commenced the study of various materials, igneous rocks and volcanic ejecta. The substances are laid out on a paper checkerboard and photographed in different regions of the spectrum, by using ray filters. Two of these pictures are reproduced on Plate VII, the upper taken by yellow, the lower by ultra-violet light. No. 1 is precipitated sulphur, almost white in visible light, black in ultra-violet. The other substances are given in the following table.

1. Sulphur
2. Zinc Sulphate
3. Kaolin
4. Talc
5. Arsenic
6. Sodium Carb.
7. Powdered Glass
8. Calcium Sulphite
9. Calcium Carbonate
10. Lead Acetate
11. Zinc Oxide
12. Shale
13. Limestone
14. Chalk
15. Trachyte
16. Clay
17. Granite
18. Rhyolite
19. Powd. Quartz
20. Granite
21. Pitchstone
22. Felsite
23. Volcanic Tuff
24. Volcanic Tuff
25. Augite

Specimens 23 and 24 are worthy of especial notice, since, they appear alike in yellow light, while in ultra-violet one is very much darker than the other.

On looking over photographs of the Moon taken at various observatories I find that the Aristarchus "black desert" is much more distinct in the pictures made on ordinary plates than on the Iso plate with a yellow screen. With my small mirror, however, I get very little trace of it except when I employ the quartz-silver filter.

It seems probable that photographs made on a larger scale will show other deposits of this material, which for the present we may name black 31, for the wave length which brings it out. Silver on glass mirrors, as I have pointed out will not be suitable. What we need is a metal speculum of long focus, say eight or ten meters. It is my hope that some observatory or amateur is already equipped for the work and will undertake it. If not, I shall have a horizontal telescope constructed for the purpose. I shall be very glad to hear from any one who wishes to carry on the investigation, and request for notice of such intention before April 1st, in order that I may be spared the expense of constructing the large mirrors myself. The preparation of suitable silver films which are structureless by transmitted light requires special precautions, and I shall be glad to furnish directions or lend my quartz plate. It is possible that a thin sheet of the new Uviol glass would do in the place of the quartz.

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PLANET ORBITS.

THOMAS CURRAN RYAN

FOR POPULAR ASTRONOMY.

Shape and Dimensions.

Though we still retain the old Greek name for this group of heavenly bodies, we have discarded the idea in which it originated. We no longer believe that they are really *planets*—that is to say, wanderers aimlessly drifting hither and thither. We believe that each of them has its own defined orbit or path in which it is compelled to travel and outside of which it is effectively prevented from straying.

Astronomers, the world over, have been an exceedingly busy lot of men during the last half century; but most of them have devoted their time chiefly to the study of regions far beyond our little solar system. Their work and discoveries in those remote skies have been productive of results well worth the time and trouble expended. Indeed, one item of knowledge obtained from observing the distant stars is indispensable to a conception of the orbits of the planets as they would appear if viewed from space outside of the solar system :—the fact that stars are drifting suggested the probability that our Sun, being one of them, is also endowed with molar motion; consequent study of star motions real and apparent has changed that suggestion into an accepted fact.

During an unmeasured period of antiquity, in the somewhat civilized lands of Chaldea, Egypt and Hindustan, the Sun, Moon, and stars, and their apparent motions, were observed by the priests; thus grew up the learning of astrology,—a compound of few facts and many fancies, of a little truth and much error, a trace of science in a body of superstition. So far as we know, the earliest correct idea concerning the solar system was conceived by Thales, a Miletian Greek, about 600 B. C. He taught that our planet is a sphere. About a century later than this, Anaximander, another Miletian, and Nicetas, a Syracusan Greek, suggested that the Earth turns daily on its axis, and their contemporary, Pythagoras, a Greek of the isle of Samos, published his theory that the Earth revolves around the Sun.

During the seven or eight centuries between Pythagoras and Claudius Ptolemaeus (better known to English speaking people as Ptolemy) no new ideas concerning the solar system were

evolved, and those already referred to—the Earth's axial rotation and its revolution around the Sun—were generally disbelieved. Ptolemy edited a great collection of the astronomical and astrological learning extant in the second century of the Christian era, but he materially assisted in postponing for more than a thousand years scientific conceptions of the solar system. This he did by discarding the teaching of Pythagoros as to the Earth's revolution around the Sun, and by advocating the false idea of the astrologers—that the Earth was at the center and Sun, Moon and stars revolving around it. This accorded with what appeared to be visual evidence, and "seeing is believing." It was accepted by the Christian world, though this class of learning was confined to the clergy until about two centuries before the discovery of America by Columbus. The Moors of Spain had brought with them the works of Ptolemy and other astronomers, and during the twelfth century translations and abridgements of some of these books were made and promulgated in England, Germany, and Castile. A zeal for astronomical research followed, and early in the sixteenth century Nicholas Copernicus, a German with an Italian name, resurrected the ideas of Pythagoras and enlarged upon them, teaching not only that the Earth revolves around the Sun, but likewise the planets, Mercury, Venus, Mars, Jupiter, and Saturn; no others had then been discovered. Soon afterward Galileo came with his invention of the telescope, then Keepler, his contemporary, and, shortly after them, Newton. The astronomy of Ptolemy was laid aside and that of Copernicus took its place. The Old made a brief struggle, but the telescope was too strong a weapon for it to cope with, and the new astronomy as expounded by these giants, Copernicus, Kepler, Galileo, and Newton, was too invincible to be overcome. The theory of Kepler that the planets travelled in closed orbits, of elliptic shape, around a stationary sun, gradually became the accepted belief of astronomers, and, until very recently, has been taught in our schools.

Nevertheless Kepler's conception, like the one which it displaced, was based upon appearances some of which have been shown by subsequent research not to be true indices of the reality; and though we still represent a planet's orbit, in our text books, as a closed ring, we have discarded two of the assumed facts upon which Kepler's theory was founded. We neither believe that the planets revolve around a fixed Sun, nor that they move in closed orbits; on the contrary we know that the Sun

is not fixed in space; that he possesses molar motion and that the planets and his other attendant bodies must therefore swing around him in open spiral paths. We are assured, however, by our text-books on astronomy, that *theoretically*, the actual conditions are the same as the supposed conditions upon which the Newtonian system of celestial mechanism was built up, and that, mathematically considered, the *actual* forces and conditions involved are just what they would be if the Sun were a stationary body. Be that as it may, the purpose of the present article is to look at the planet orbits as they would appear if observed from a point in space outside of the solar system,—in other words, to show them just as they are, freed from all appearances that do not represent reality.

To be exact it must be said that even before the molar motion of the Sun was discovered it was not assumed that he was in a state of absolute rest; the vicissitudes of conjunctions, aphelions and perihelions, combining, distributing and varying the attractive forces of planets and other attendant bodies revolving about him, would of necessity move him slightly hither and thither; but this fluttering motion would take place within a region of space not appreciably larger than his own periphery and would not be of sufficient importance to prevent the force of gravitation and the centrifugal motion of a planet from combining to produce a closed orbit, provided they could cause such an orbit if the Sun were absolutely at rest.

If we desire to successfully study any thing, it is always well to begin if we can by looking at the thing,—seeing it just as it is. If we cannot do that, it will answer almost as well to draw a picture of the thing, provided we are able to obtain from any source knowledge sufficient for that purpose. Now, although on account of their great distance from us the very rapid motions of the planets are apparently so slow that they do not disclose themselves at all to the eye of the observer, yet by constant observation of changes in their positions, and variations in the apparent sizes of their disks indicating displacement as to distance from us, we acquire facts from which reliable diagrams can be made. What those diagrams may picture is another question; they may actually depict the orbit of the planet observed, or they may represent the Earth's orbit as reflected in the apparent motion of another planet. In this way the orbit of our planet has been very graphically shown by observing Jupiter.

Figure I is a diagram of the path upon which Jupiter *appears*

to travel, as observed from the Earth, during a period of six years. The figure represents six coils of a spiral. The Earth makes almost twelve loops of its spiral orbit around the Sun while Jupiter is making only one. Jupiter's orbit is therefore straight enough, as compared with that of the Earth, to reflect with approximate accuracy our actual motion. Our successive spirals carry us upward and downward and to the right and left; but, as we cannot see our own motion, and as we do see Jupiter between us and the stars, it seems to us as if Jupiter were moving upward when we move downward, away from us when we recede from him, and so on, so that this image of a spiral which Jupiter appears to trace out on the sky is only a reflection of what our own planet is doing. Figure I represents only this reflected motion of the Earth. If Jupiter's real motion were added to it, as it actually is, and must be, in observations made from our *inside* station, the chain of spiral coils shown will be bent so that 11.85 of them would make a ring of

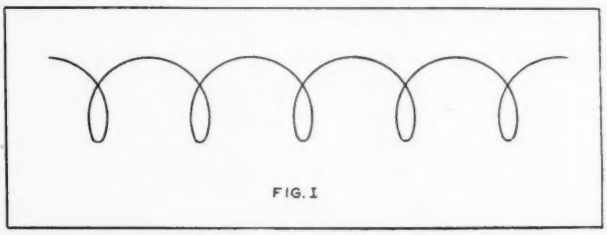


FIG. I

coils, representing the 11.85 revolutions of the Earth that occur during one of Jupiter's swings around the Sun. Such a figure is shown in Young's General Astronomy, page 321,—a drawing made by Cassini two hundred years ago, to represent the real and apparent motions of Jupiter from 1708 to 1720 A. D. As Cassini died in 1712, at the age of eighty-seven years, the greater portion of this diagram must represent his prophesy of what would occur, based no doubt upon actual observation of what had taken place before. He was a great astronomer and made several important discoveries, among them four of Saturn's moons. As nothing was known in his day of the Sun's translation through space, he naturally interpreted the phenomena pictured in his diagram as representing the revolution of the Earth and Jupiter around a stationary sun. But with our present knowledge we are obliged to interpret the ring in his diagram as showing one coil of Jupiter's spiral orbit, and each of the loops composing the ring as one spiral revolution of the

Earth around the Sun. Therefore, if we abstract from Cassini's figure such portion of it as represents the actual motion of Jupiter, retaining only what reflects the motion of the Earth, we should have remaining a spiral in the form of Figure I, each coil of which shows a single orbital revolution of the Earth. It could, however, be thus seen only from space outside of Jupiter's orbit.

It is readily inferred that similar observations of Saturn would result in the same kind of diagram, only that instead of 11.85 small coils there would be 29.46 of them in that case. Uranus and Neptune are so distant that the apparent change in size of disk on account of the Earth's spiral swing would perhaps be too small for accurate observation. As Mercury makes four spiral revolutions in its orbit while the Earth is making one, it should exhibit a similar diagram, but in that case the four small loops would picture that planet's motion while the ring embodied in the aggregated loops would represent the actual motion of the Earth reflected as an apparent motion of Mercury.

It is not supposable that a picture of the Earth's orbit obtained by Cassini's method can be relied upon as representing accurately the dimensions of the orbit in which a single revolution occurs. We get from it scarcely more than the idea that it is spiral in shape. A better way to obtain a diagram which will represent with approximate accuracy the dimensions of the Earth's orbit was shown in my second article upon "The Solar Apex" published in POPULAR ASTRONOMY, vol. xv, page 336, and will be here re-stated:—

Let the cylinder of space around which the Earth swings in its helicoidal journey be conceived as enclosed by a shell, and a section of this shell severed sufficiently long to contain a single year's journey of the Sun. Let it be further imagined that this severed section of the shell is slit through one side, longitudinally, and the cylinder flattened out. We can represent it now by the diagram, Figure II, which is proportioned to show a width, from left to right, of 396,000,000 miles, being one year's journey of the Sun, and a height, from bottom to top, of 584,000,000 miles, being the circumference of the Earth's relative orbit, or, in other words, the circumference of that cylinder of space around and upon which the Earth's helicoidal path runs. The diagonal line, drawn from corner to corner of the figure, shows that path, and represents according to the proportions of the figure, a distance of 703,000,000 miles, being the length of one year's actual journey of the Earth, the direc-

tion of motion being from the upper left-hand corner to the lower right-hand corner. If we cut a piece of pasteboard of length and width proportioned to this figure, draw a line upon it from corner to corner and bring the top and bottom edges together, leaving the diagonal line outside, we change the paper into a cylinder and the diagonal line into one coil of a spiral. The speed assumed for the Sun in this diagram is the one now most generally accepted—that found by Campbell, twelve and a half miles per second.

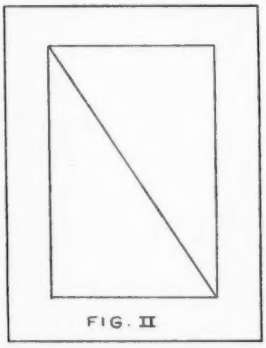


FIG. II

It will be shown in a subsequent article that the cylinder of space, around and upon which the Earth moves in its actual path, cannot be represented with exactness in this way :—that a section of it equivalent to a year's journey of Sun and Earth would not be exactly a right cylinder; it would be somewhat oblique. But, in order to confine ourselves to one thing at a time, and as the dimensions of the orbits will not be materially altered by adding the element of obliquity, let us adopt this rectangular figure for the time being as a means of picturing the dimensions of the orbits of all the planets.

Explanations of Figures III and IV:—These figures show the length and breadth dimensions of surfaces of the cylinders of space around and upon which the several planets move in their helicoidal paths, assuming that the Sun travels at the rate of twelve and one-half miles per second. The Sun's way must be considered as progressing from left to right, so that the lateral dimension of each diagram in the figure shows the distance he travels during one of the planet's periods, or swings, around him, while the vertical dimension shows the circumference of the cylinder of space around and upon which that swing is made, and the diagonal line shows the actual dis-

tance travelled by each planet during one such revolution, the direction of the planet's motion being, in each case, from the upper left-hand corner to the lower right-hand corner. The difference is so great in size, between the orbits of the four inner and four outer planets, that they cannot all be shown upon the same scale, the page not being large enough to contain dia-

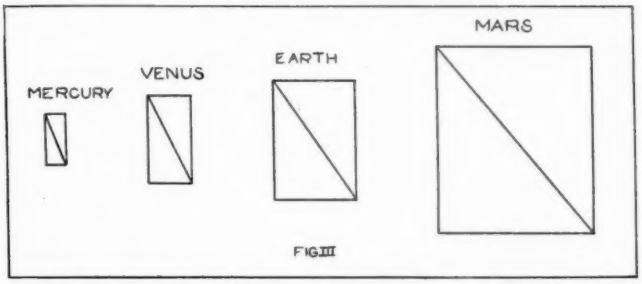


FIG.III

grams for the four outside planets upon a scale extensive enough to give a fair idea of the others; therefore these diagrams are made on two scales: one for Mercury, Venus, Earth and Mars of 400,000,000 miles to one inch, and another for Jupiter, Saturn, Uranus and Neptune of 8,000,000,000 miles to one inch, the two scales comparing to each other as 1 to 20, so that in

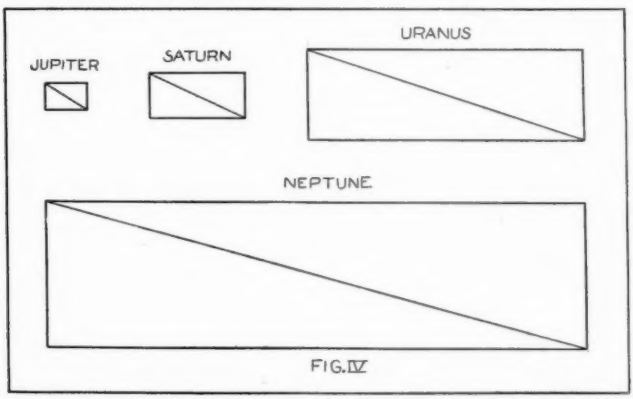


FIG.IV

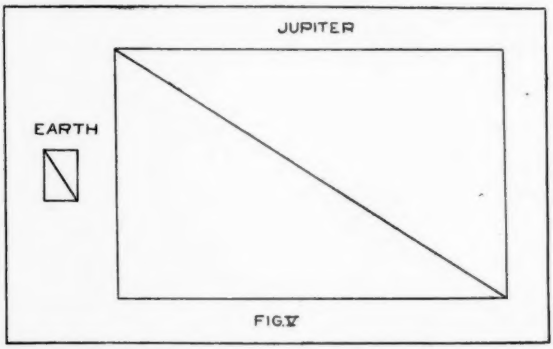
order to compare a diagram of Figure III with one in Figure IV the reader must imagine the latter increased to twenty times its present size.

In order to give a stronger impression of the actual differences in dimensions between the orbits represented in Figures III and IV I subjoin, as Figure V, diagrams representing those features

of the orbits of Earth and Jupiter upon the same scale. It will be seen that Jupiter's diagram which in Figure IV is shown much smaller than thar of the Earth in Figure III, is, when both are reduced to the same scale, many times larger, as shown in Figure V.

The reader will, of course, notice the marked and regular gain in that dimension of these figures which coincides with the Sun's path, over the other dimension representing the circumference of each orbit, according as the mean distances of the planets from the Sun are increased.

I wish to emphasize a point before intimated, in connection with the use of these diagrams in Figures II to V inclusive, for obtaining a conception of the actual helicoidal path in which a planet moves. As before stated, each of them is designed to show the flattened-out surface of the cylinder of space around



and upon which the planet describes its helicoidal path during a single revolution. Therefore the real fact that must be thought about when observing these figures cannot be *diagramed*. But it is one that can be *seen* if the reader will use each diagram in the manner described in connection with Figure II,—cutting out pieces of card board or heavy paper, in the proportions of length and breadth given in the diagrams, and bringing the top and bottom edges together so as to form a paper cylinder. The Sun's path will be from left to right, and close enough to the axis of the cylinder to show the perihelion and aphelion distances of the planet; the diagonal line will then be changed to a spiral, representing the planet's helicoidal path.

The planet would move upon the straight path represented by the diagonal line in each figure, were it not for the attraction of the Sun and planet for each other, which has the same

effect as is obtained by the reader when he folds the paper rectangle into a cylinder:—that is, the straight line on which the planet's own impulse of simple motion would carry it is warped from moment to moment by that attraction, just in the same way that a ship's course may be warped by the helm. In the case of the planet, velocity, mass and distance are so nicely counterbalanced that the spiral shape of the orbit has been produced and repeated year after year for countless ages. Whether this fact of revolution in a spiral orbit is or is not sufficiently accounted for by the Newtonian scheme of celestial mechanics is a question of the similarity of forces and conditions between the two cases of a planet revolving around a fixed Sun and one which is being translated through space along with the Sun around which it revolves. If the forces and conditions are the same in both cases, then inasmuch as we know that the spiral orbit is actually occurring the inference would be irresistible that if the Sun was standing still the revolution of the planet would take place in a closed, ring-like orbit.

Wausau, Wisconsin.

SIRIUS THE DOG-STAR.

ARTHUR K. BARTLETT

FOR POPULAR ASTRONOMY.

The charming study of astronomy has afforded few revelations more wonderful and interesting than those relating to the "king of suns" which, owing to its remarkable brilliancy and superior magnitude, must have attracted the attention of all persons who enjoy an occasional survey of the heavens at this season of the year. From time immemorial this majestic star has been observed with the greatest solicitude by poets, divines and philosophers, and is known to astronomers by the name of Sirius—the famous "Dog-Star" of the ancients. During the winter season it glows upon the evening sky with a luster unequaled by any other star in the firmament, and owing to its location, being situated only about sixteen degrees south of the celestial equator, and nearly midway between the two poles of the heavens, it is visible from every habitable portion of the Earth, but in our latitude it may be seen to the best advantage during the latter part of the winter, when it appears toward the south at an early hour in the evening.

Sirius, after it has once been identified and carefully located among the neighboring stars, may be easily recognized at any time during the winter, for owing to its attractive appearance and superior brilliancy, when seen on a clear night by an attentive observer, it will never be forgotten. There is no other star in the heavens that has been more universally observed, and around which there clusters so many ancient associations and superstitions, or has received more attention, both from astronomers and the general public, than this glorious orb. Whoever has looked upon the beautiful star, located in the brightest region of the heavens, and seen it glowing on a clear winter evening, must have beheld with awe and admiration its indescribable splendor; and one need not be an astronomer to admire its radiant glory, or to conclude that this charming orb possesses characteristics distinguishing it from any other star in the firmament. Sirius crosses the meridian about four minutes earlier each evening, and shines with a brilliancy which cannot fail to arouse the interest and curiosity of the most casual observer. But if one watches Sirius when on the horizon, either rising or setting, it will be noticed that it not only changes in appearance but seems also to blaze forth in different colors, especially on a clear and cold winter evening when the Moon is absent and the stars are observed to "twinkle" more than usual. Sirius appears farther toward the south than any of the bright stars of winter visible in our latitude, being about one-third of the way up to the zenith when at its greatest elevation, and is above the horizon only ten hours out of each twenty-four.

In ancient times, when every man was his own astronomer, the rising and setting of Sirius was watched with great solicitude. The ancient Thebans, who first cultivated astronomy in Egypt, determined the length of the year by its risings, and it was, to a certain extent, the almanac of the ancient Egyptians, who observed its rising with mingled apprehensions of hope and fear. Every year the appearance of this well-known star, just before the rising Sun, was followed by the rising of the river Nile, and thus it was like a faithful watch-dog, giving warning of the approaching overflow of the waters, for which reason it received the name of "Dog-Star." To that season of the year when Sirius rose with the Sun, and seemed to blend its own influence with the heat of that luminary, the ancients gave the name of "dog-days." At that remote period they commenced on the 4th of August, or four days after the summer solstice, and continued forty days, or until the 14th of September. But

the rising of Sirius varies with the latitude of the place, and in the same latitude is perceptibly changed, after a course of years, by what is known as the precession of the equinoxes. The modern "dog-days" extend from the 3rd of July to the 11th of August, being one day less than the ancients reckoned, and it will therefore be readily seen that they have no reference whatever to the rising of Sirius with the Sun, which occurs at present about the 12th of August. Sirius is with us overhead in the daytime during the so-called "dog-days," and consequently invisible, and is at night in the lower hemisphere, but is visible and conspicuous to us upon the nocturnal sky all through the winter.

Sirius belongs to the little constellation Canis Major or the Great Dog, a group of thirty-one stars situated just south and east of Orion, and almost universally known from the unrivaled brilliancy of its leading orb, but which otherwise possesses no noteworthy attractions. A line drawn from the star Aldebaran through Bellatrix, toward the southeast, will indicate the position of Sirius, which forms with Procyon and Betelgeuse a large triangle, the sides of which are nearly equal. It is also pointed out by the three stars in the "belt" of Orion, its distance from them being about twenty-five degrees toward the southeast. When observed through a large telescope Sirius presents a charming appearance, and shines with a brilliancy that is startling to the beholder. It is not only the brightest star in the heavens, but is more than three times brighter than an ordinary first-magnitude star, and is believed to be 500 times as bright as a star of the sixth magnitude—the faintest visible to the naked eye.

Owing to the remarkable size and brilliancy of Sirius, it was once naturally regarded as the nearest of the stars, but its distance is in reality so great that it has never been satisfactorily determined. Some reliable authorities, however, assign to Sirius a distance of 100 trillions of miles, which is four times the distance of Alpha Centauri—the nearest star known to astronomers—and a million times the Sun's distance from our Earth. Professor Chambers, in his recent work, "The Story of the Stars," places Sirius as the fourth in order of distance among those stars experimented upon, whose parallax has been measured for the purpose of ascertaining their distances from us. It is estimated by some astronomers that the brilliancy of Sirius is 300 times greater than that of the Sun, and if we assume that the intrinsic brightness of its surface is the same as the Sun's, the surface of this star must be 300 times larger than

that of the Sun, from which it follows that the diameter of Sirius is about eighteen times that of the Sun, and its volume about 2,200 times greater. This splendid star is in reality a globe emitting so enormous a quantity of light and heat, that were it to take the place of our Sun, every creature on this Earth would be consumed by its burning rays.

According to Professor Newcomb, in his recent book on "The Stars," Sirius is thirty times more luminous than the Sun, and its parallax is 37/100 of a second, which corresponds to a distance of at least fifty-one trillions of miles, or about twice that of the nearest star and over 500,000 times the Sun's distance from us; and if these figures are correct, its light would require over 8½ years to reach the Earth. Different astronomers, after careful investigations, have assigned various values to the size and distance of Sirius, but the latest estimates, based upon the recent determination of its parallax, are accepted as the most reliable results, and are doubtless nearer the actual values than those long regarded as correct and given in our text-books on astronomy until of late. While Sirius was formerly believed to be much farther away, it is one of the stars at present known to be comparatively near to us, and in fact, there are only four other stars in the heavens that are known to be nearer.

By means of the spectroscope it has been found that Sirius is receding from our Earth at the rate of twenty-six miles per second; and yet, even with this almost incredible velocity, the passage of a thousand years will make no perceptible difference in the appearance of this brilliant star, so immense is the distance which separates it from us. Sirius is located in that part of the heavens from which the Sun is receding at the rate of twelve miles per second, and its proper motion is such as to have carried it across the Milky Way in ten thousand years according to Professor Serviss in a recent article which suggested to Ella Wheeler Wilcox her excellent poem entitled "When Sirius Crossed the Milky Way;" and there is said to be a tradition that Sirius was seen by the men of the Stone Age on the opposite side of the Galaxy to that on which it is now located. Sirius, on account of its brilliancy and prominence, was regarded by Kant, the celebrated German philosopher, as the central Sun of the universe, but his conclusion, though a grand and natural one, has been shown to be erroneous, and astronomers do not recognize any particular star as the center around which all the other stars revolve. It is believed that remarkable changes have taken place in the color of Sirius since it was first observ-

ed by astronomers. Sirius was described by the ancients as a fiery red star. Many years ago it was said to be pure white, but it is now becoming of a decided green color, as a careful observer will readily perceive when this star is visible on a clear winter evening.

Secchi, the eminent Italian astronomer, divided the stars into four types, according to their spectra, and Sirius belongs to the first type, in which it holds a leading position, and which includes the highest conditions of development in the stellar universe. We may justly consider this glorious Sun as the center of a system of revolving worlds, and imagine them as being inhabited by creatures far more advanced in intellectual development than ourselves. Sirius, though the brightest star in the heavens and long known as the "King of Suns," is now believed to be exceeded in actual size by Canopus, Antares, Rigel, Spica and Arcturus, the latter probably being at least a thousand times more luminous than our Sun, but all these stars are much farther away, less prominent, and do not possess the interest or importance attached to the "Dog-Star" from the earliest ages. We receive from Sirius only one seven-billionth of the light that the Sun gives us, but the star in reality gives out about forty times as much light as the Sun. It is a very gaseous and expanded body, however, and though very much larger and more brilliant than the Sun, is comparatively light in weight, its mass exceeding that of the Sun only about twenty times.

The late Professor Proctor, referring to this interesting orb, says: "Sirius shines at least 200 times as brightly as our Sun would shine if set beside it. Assuming its surface to be equally brilliant, this would imply in comparison with our Sun, a diameter fourteen times and a volume 3,000 times as great. Its luster, however, seems higher than the Sun's, but, even making allowance for that, we must still consider this giant Sun to be at least 1,000 times as large as our own orb. Recent evidence tends to show that its rate of recession from us is diminishing, so that we may expect this to change into a motion of approach. Here is a hint that Sirius is traveling in a mighty orbit, with movements carrying it alternately from and toward us." It is interesting to know that the two concluding sentences of Professor Proctor's remarks, written many years ago, may well be regarded, in the light of recent developments, as a real prophecy that has been partially fulfilled, inasmuch as the motion of Sirius away from us has not only been diminish-

ing, but the star is now known to be actually gaining upon us and overtaking the Earth and Sun at the rate of ten miles per second, notwithstanding the fact that we are receding from it with great velocity as already mentioned. It now only remains to prove that Sirius is moving in an immense orbit around some unknown center to complete the above prophecy, thereby establishing the accuracy of Professor Proctor's statements and giving them special significance in their relation to our knowledge concerning this famous celestial object.

One of the most interesting results of the observations directed to this wonderful star was the discovery that it is attended by a revolving companion or satellite, the existence of which had long been suspected by astronomers, and which was finally detected by mere accident. The presence of this object had been revealed by the effect of its attraction upon Sirius, the motion of which varied in such a way as to indicate a powerful disturbing influence in its vicinity. The famous German astronomer, Bessel, about seventy years ago expressed his belief that the periodical variations in the motion of Sirius were produced by the attraction of an invisible companion, revolving around the gigantic star. Several astronomers had calculated the orbit of the attracting body, and its distance from Sirius at various times, and though it was diligently searched for, it continued to elude detection, even by means of the most powerful telescopes. But in February, 1862, the eighteen-inch telescope which was being constructed for the Chicago observatory was pointed to Sirius as a test of its power, when the disturbing companion came suddenly into view at a distance of about ten seconds from the large star, and exactly in the direction which had been predicted for that time. The period of its revolution around Sirius was found to be nearly fifty years, and within a few months of the period calculated by Bessel, long before the telescope had revealed its presence.

When the news of its discovery had spread in every direction, all the great telescopes were pointed to Sirius, and it was found that when its exact position was known, it could be easily detected by skillful observers, even with smaller instruments than the one which first brought it into view, the visibility of this very interesting and difficult object depending almost as much upon the altitude of Sirius and the condition of the atmosphere as upon the power of the telescope employed by observers. In a recent magazine article entitled "To Measure the Heat of a Star," the writer says: "Sirius, the Dog-Star, which has twenty

times the mass and sixty-three times the brightness of our Sun, travels with a companion that possesses only one ten-thousandth part of its luminosity. It would seem as if the latter must be a very old and nearly extinguished Sun—far gone in decrepitude, as one might say."

It is a remarkable circumstance that Voltaire, who like Dean Swift in his "Gulliver's Travels," attributed two satellites to the planet Mars long before they were discovered or even suspected by astronomers, should also, in his story of "Micromegas," have imagined and described an immense orb revolving around Sirius, many years before its existence had been revealed by the telescope. The hero of his wonderful story came from this imagined planet, and was described as a giant, more than twenty miles tall, who made a visit to the microscopic inhabitants of our Earth. We find, then, that Sirius is a "double star," the two components being physically connected, and forming what is known as a "binary system," the smaller star revolving around the larger, or both around their common center of gravity. Owing to certain irregularities in the motion of the smaller star, which cannot be explained, some astronomers are of the opinion that Sirius has another disturbing companion, the existence of which is indicated by its attraction only, and which may eventually be discovered, either by one of the great telescopes already constructed or the still larger instruments now in contemplation for the near future.

Battle Creek, Michigan.

THE INEQUALITY OF THE ILLUMINATION OF THE MOON DURING ECLIPSE.

JOEL H. METCALF

FOR POPULAR ASTRONOMY.

On October 16, 1902, there was a total eclipse of the Moon which was notable from the fact that the illumination of the eclipsed Moon was very uneven. At 12:22, standard time, the Moon had a dark band running through it nearly east and west.

The phenomenon was so conspicuous that I attempted to photograph it but failed utterly as the eclipsed Moon had such slight actinic power. The phenomenon revealed the fact that the section of Earth's shadow must, at least at times, be very unequally illuminated. I determined therefore at the first op-

portunity to take a picture which I believed would in part reveal that inequality. If the Moon were large enough to fill the entire Earth's shadow, it is evident that a photograph taken at that time would not only be a photograph of the Moon but would reveal any such difference of illumination if it existed. As the Moon is not large enough for this purpose, it occurred to me that if the totally eclipsed Moon were allowed to trail through the Earth's shadow it might reveal more or less clearly the conditions of illumination within the shadow. It is evident that as the exposure must be limited to the time of totality to prevent fogging of the plate by the sun-illuminated Moon that some parts of the section of the shadow could receive much more exposure than others. The times will vary from a few seconds in some parts to twenty-five minutes in others. Again the different reflecting power of different parts of the Moon will introduce some slight inequalites. But on the whole and in a general way such an exposure ought to reveal the illumination of a small part of the shadow cone at the distance of the Moon.

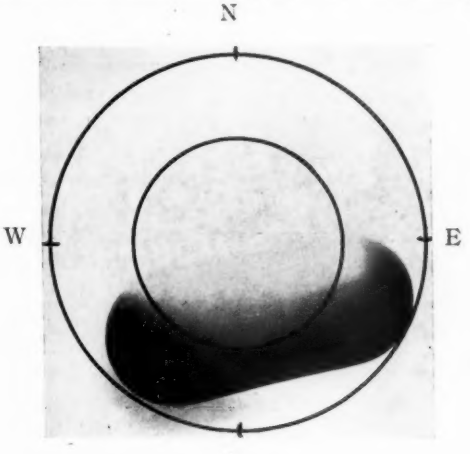
The enclosed photograph is the result of such an attempt. The plate was exposed during the eclipse of November 26, 1909, from $20^h\ 13^m\ 30^s$ to $21^h\ 34^m\ 0^s$ Gr. M. T. The telescope was set on a star in the region of the eclipsed Moon and the star was followed during the exposure. No account was taken of the motion of the Earth's shadow during the interval. As this was only one-fifteenth of the motion of the Moon, the amount would be inappreciable.

An examination of the resulting plate gives the following results : (1) Some of the more prominent markings on the Moon show very faintly as lines running in the direction of the Moon's motion. (2) In spite of the long exposure of some parts of the Moon the resulting image is nowhere over-exposed. The actinic power of the light in the Earth's shadow is very slight everywhere and almost entirely disappears at a distance of seven-twelfths of the radius of the Earth's shadow. The illumination of this inner part cannot be much more than twice as great as the general illumination of the sky.

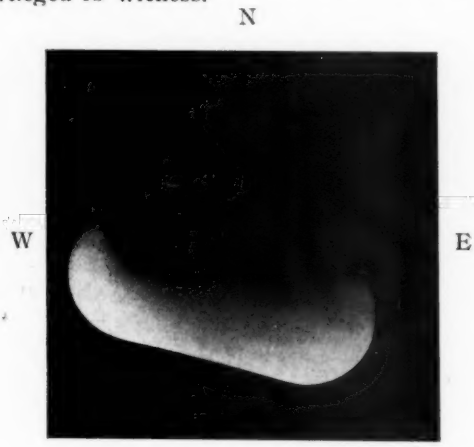
From the accompanying photograph one can locate the center of the Earth's shadow with considerable accuracy without any reference to a Nautical Almanac.

In addition to this there is evidence of inequality which cannot be accounted for as due to unequal exposure. The illumination at the ends differs considerably as an inspection of the

photograph will show. This it seems to me must be caused by unequal illumination due doubtless, to the varying conditions of the Earth's atmosphere through which the sunlight was re-



fracted to reach the Moon. A total eclipse of the Sun by the Moon is for us perhaps the most striking celestial phenomenon we are privileged to witness.



How much more wonderful would an eclipse of the Sun by the Earth be it we could witness it from the Moon where not only the greater apparent size of the Earth would add awe to the

spectacle but the varying transparency of the Earth's atmosphere would introduce elements spectacular in the extreme which we miss around the airless Moon.

In regard to the photographs, one is a direct positive, the other is a negative made from a positive on glass. I have included the positive so that the position of the Earth's shadow and its comparatively unilluminated center can be shown roughly drawn to scale. The inequality of the shadow is also clearly shown. It must not be forgotten that in changing from posive to negative the east and west points are reversed.

Taunton, Mass.

ATMOSPHERIC REFRACTION NEAR THE HORIZON.

GEORGE C. COMSTOCK

For Popular Astronomy.

In connection with controverted questions of polar exploration I have recently had occasion to deal with altitudes of the Sun observed near the horizon and have been somewhat embarrassed by the refraction correction. The ordinary refraction tables *e. g.* Bessel's, are far from convenient when great zenith distances are involved and fail absolutely in a class of cases not infrequent, viz. the observed rising or setting of a celestial body seen from an elevation so considerable that the dip of the horizon becomes an important element. The tables published by Radau, *Annales de l' Observatoire de Paris, 1889, Mémoires, Tome 19*, furnish the most ready exit from such difficulties, since they extend to a zenith distance of 91°, and their unusual form is, in this particular case, much more convenient than the classical one introduced by Bessel. In absolute value these refractions, at the horizon, differ very little from those of Gyldén, commonly called the Pulkowa refractions.

For my own use I have constructed from Radau's rather voluminous tables a brief compilation that has proved so convenient that it is given herewith for the use of others who may have occasion to deal with similar problems. In view of the uncertainty attending observations made very near to the horizon, the tabular numbers are cut down from the hundredth of a second, as given by Radau, to tenths of a minute, which seem more consonant with the degree of precision actually attainable and which permit the omission of some minor refinements that considerably complicate the use of the original tables.

ASTRONOMICAL REFRACTIONS NEAR THE HORIZON.

Temperature 0° Fah.
Table I

h	a	R	
°	′	′	
−2	+ 60	118.	52.
−1	56	66.0	24.2
0	55	41.6	13.0
+1	59	28.6	7.5
2	64	21.1	4.7
3	72	16.4	3 1
4	81	13.3	2.2
5	91	11.1	1.6
6	101	9.5	1.2
7	111	8.3	1.0
8	122	7.3	0.7
9	134	6.6	0.7
+10	146	5.9	

Barometer 30 inches
Table II

R	b
′	′
0	+0.0
10	0.3
20	0.7
30	1.1
40	1.5
50	1.9
60	2.4
70	+2.9

The argument, h, of the first of these tables is the apparent altitude of any celestial body and the function, R, is the refraction corresponding to the normal atmospheric condition defined by a barometric pressure of thirty English inches of mercury and a temperature of 0° Fahrenheit. To adapt the tabular R to any other state of the meteorological elements the temperature correction is first applied in the form of an increment, Δh, to the argument with which R is to be interpolated. Let t represent the temperature of the air in degrees Fahrenheit and a a quantity interpolated from Table 1 with the observed altitude, h, as argument, then will Δh be given by relation

$$100\,\Delta h = a\,t.$$

With the R corresponding to $h + \Delta h$ as argument the quantity b is next to be interpolated from Table II and the barometer correction to R is given by

$$\Delta R = +b(B - 30)$$

where B, in English inches, denotes the barometric pressure reduced to the freezing point. This reduction to the freezing point is most conveniently taken from meteorological tables, but in their absence it may be ignored in most cases or, if necessary, computed with sufficient precision from the formula

$$10000\,\Delta B = B(32° - T)$$

where T is the reading of the attached thermometer. The refraction to be finally adopted is $R + \Delta R$.

Radau illustrates the use of his tables by an example whose data when transformed into the units here employed are as follows :

Obs'd h	4° 44′.8	Barom.	29.685
Ext. Temp.	54°.5 Fahr.	Att. Ther.	50°

Corresponding to these data we find

h	4° 44′.8
a	+88 .5
t	+54 .5
Δh	+48 .3
$h + \Delta h$	5 33 .1
R	10 .2
B'	29 .68
$\Delta B'$	— .05
$B' + \Delta B - 30$	— 0 .37
b	+ 0 .3
ΔR	— 0 .1
Refraction	10 .1

Corresponding to the above data Radau finds for the amount of the refraction, 10′ 6″, the Pulkowa tables give 10′ 3″, and Bessel (Tab. Reg.) 10′ 5″.

Washburn Observatory,
Madison, Wisconsin.

REDUCTION OF POLARIS VERTICAL CIRCLE OBSERVATIONS FOR TIME AND AZIMUTH.

G. O. JAMES

For Popular Astronomy.

The rigorous formulae for the computation of the chronometer correction from the transit of a southern star across the vertical circle through Polaris are :

$$t - t_0 = (\mu - \mu_0) - (\alpha - \alpha_0)$$

$$\tan \xi = \frac{\tan p_0 \sec \delta \sin (t_0 - t)}{1 - \tan p_0 \tan \delta \cos (t_0 - t)}$$

$$\tan x = \tan \xi \sin \delta$$

$$\sin m = \tan \xi \cos x \tan \phi \cos \delta$$

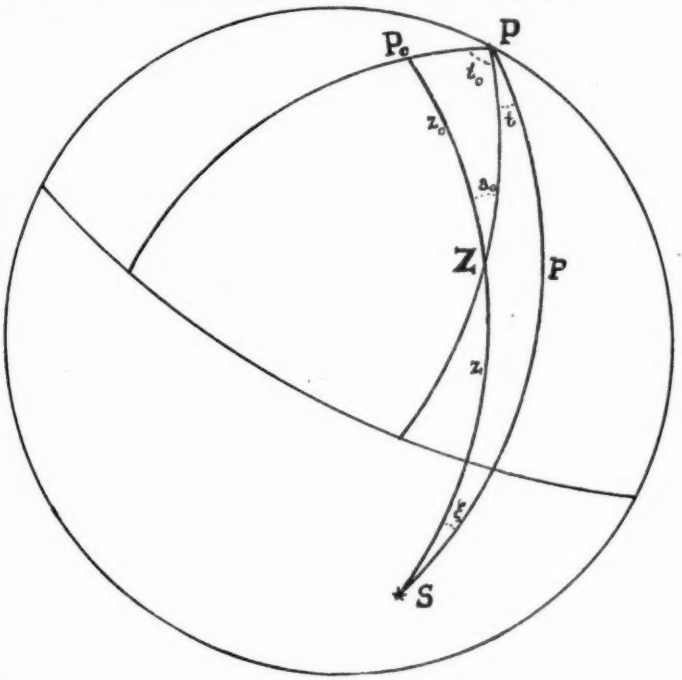
$$\Delta\mu = \alpha - \mu + x - m + i \sec \phi + c \sec \phi \frac{\cos \tfrac{1}{2} (z - z_0)}{\cos \tfrac{1}{2} (z + z_0)}$$

where

μ = chronometer time of transit of star
t = hour angle of star
p = polar distance of star
ξ = parallactic angle of star
x, m = auxiliary angles
i, c = inclination and collimation constants

and subscript ($_\circ$) refers to Polaris.

For observations made with an engineer's transit or small theodolite, five place logarithms may be used in the computation and the log $\frac{1}{1-a}$ taken from a special table with log a as argument. The use of this special table may be avoided and the calculation much simplified by the following method.



In the figure, let $P_\circ$ be Polaris and S the southern star, and set

$$\sigma = SP_\circ - SP = (z + z_\circ) - p.$$

This *reduction to the Pole* is then developable in a power series in $p_\circ$, the polar distance of Polaris, and by the same me-

thod used in developing the reduction to the Pole in determining latitude from an observed altitude of Polaris, we have

$$\sigma = -p_o \cos (t_o - t) + \frac{p_o^2}{2} \tan \delta \sin^2 (t_o - t)$$
$$+ \text{terms of third and higher powers in } p_o.$$

Again, from the figure

$$\sin \xi = \frac{\sin p_o \sin (t_o - t)}{\sin (z + z_o)}$$
$$= \sin p_o \sec (\delta - \sigma) \sin (t_o - t).$$

Neglecting terms of the third and higher powers in ξ and p_o,

$$\xi - \frac{\xi^3}{6} = \left(p_o - \frac{p_o^3}{6}\right) \sec (\delta - \sigma) \sin (t_o - t)$$

$$\xi = p_o \sec (\delta - \sigma) \sin (t_o - t) + \frac{p_o^3}{6} \left\{ \sec \delta \sin (t_o - t) - \sec^3 \delta \sin^3 (t_o - t) \right\}.$$

Setting

$$\epsilon = -p_o \cos (t_o - t) + \frac{p_o^2}{2} \sin^2 (t_o - t)$$

$$\sec (\delta - \sigma) = \sec (\delta - \epsilon) + \frac{p_o^2}{2} \sec \delta \tan \delta (1 - \tan \delta) \sin^2 t_o - t)$$
$$+ \text{terms of third and higher powers in } p_o.$$

$$\xi = p_o \sec (\delta - \epsilon) \sin (t_o - t)$$
$$+ \frac{p_o^3}{6} \left\{ 3 \sec \delta \tan \delta (1 - \tan \delta) \sin^3 (t_o - t) - \sec \delta \sin (t_o - t) \right.$$
$$\left. + \sec^3 \delta \sin^3 (t_o - t) \right\}.$$

Similarly, from

$$\tan x = \tan \xi \sin \delta$$
$$x = \xi \sin \delta + \frac{\xi^3}{3} (\sin \delta - \sin^3 \delta)$$

and from

$$\sin m = \tan \xi \cos x \tan \phi \cos \delta$$

$$m = \xi \tan \phi \cos \delta + \frac{\xi^3}{6} \left\{ 2 \tan \phi \cos \delta - 3 \tan \phi \cos \delta \sin^2 \delta + \tan^3 \phi \cos^3 \delta \right\}.$$

Combining these values of ξ, x, and m:

$$x - m = \xi \frac{\sin (\phi - \delta)}{\cos \phi} + \frac{\xi^3}{6} \left\{ \frac{2 \sin (\phi - \delta)}{\cos \phi} \cos^2 \delta + \tan^3 \phi \cos^3 \delta - \tan \phi \cos \delta \sin^2 \delta \right\}$$
$$= p_o \frac{\sin (\phi - \delta)}{\cos \phi} \sec (\delta - \epsilon) \sin (t_o - t)$$
$$+ \frac{p_o^3}{6} \left\{ \frac{3 \sin (\phi - \delta)}{\cos \phi \cos \delta} + \tan^3 \phi \right\} \sin^3 (t_o - t) - \frac{p_o^3}{6} \frac{\sin (\phi - \delta)}{\cos \phi \cos \delta} \sin (t_o - t)$$
$$+ \frac{p_o^3}{6} \left\{ \frac{\sin (\phi - \delta)}{\cos \phi \cos \delta} (3 \tan \delta - 2 \tan^2 \delta) - \tan \phi \sin^2 \delta \right\} \sin^3 (t_o - t)$$
$$+ \text{terms of fourth and higher powers in } p_o.$$

Hence, *to within terms of the third power in* p_o:

$$x - m = p_o \sec \phi \sin (\phi - \delta) \sec (\delta - \epsilon) \sin (t_o - t).$$

This expression is especially adapted to logarithmic computation, for the small angle ϵ is published each year in the back of the *American Ephemeris* and *Nautical Almanac* with $t_0 - t$ as argument.

If, therefore, the error committed by neglecting the terms of third and higher orders in p_0 is admissible, we have a very simple form for the reduction;

Now $\frac{p_0^3}{6} = 0^s.02$ very nearly, and for latitudes less than 70°

$$\frac{\sin(\phi - \delta)}{\cos\phi \cos\delta} < 2.75.$$

The middle term of the correction is then

$$\frac{p_0^3}{6} \frac{\sin(\phi - \delta)}{\cos\phi \cos\delta} < 0^s.055$$

and hence the first and third terms furnish the principal part of the correction, becoming large for high latitudes. For $\phi = 70°$ and $\delta = 0°$ the corrective term is nearly equal to $0^s.6$, an inadmissible value, while for $\phi = 45°$ and $\delta = 0°$ it is less than $0^s.1$. We may then say :

For middle latitudes the approximate formula :

$$x - m = p_0 \sec\phi \sin(\phi - \delta) \sec(\delta - \sigma) \sin(t_0 - t)$$

will give a value of the chronometer correction to within $0^s.1$.

This then is the type of reduction formula most advantageously used in work with the engineer's transit, where the errors of observation are themselves likely to be large, and we may write the following reduction formulae :

$$t - t_0 = (\mu - \mu_0) - (\alpha - \alpha_0)$$

$$t = p_0 \sec\phi \sin(\phi - \delta) \sec(\delta - \epsilon) \sin(t_0 - t)$$

$$\theta = t + \alpha$$

$$\Delta\mu = \theta - \mu + i \sec\phi + \sec\phi \frac{\cos\frac{1}{2}(z - z_0)}{\cos\frac{1}{2}(z + z_0)}.$$

The inclination and collimation corrections are best eliminated by the method of observation and this may be done by choosing two southern stars of nearly the same declination, observing one in the direct and the other in the doubly reversed position of the instrument. If the plate level bubbles are kept in the center both i and c change sign on double reversal, and hence these corrections disappear from the mean.

Below is given an example of such an observation, the *observed* values being taken from *Laws Observatory Bulletin No. 5.*

LAWS OBSERVATORY, NOVEMBER 8, 1904.

	θ Piscium E	i Piscium W
μ	$23^h\ 16^m\ 12^s.6$	$23^h\ 28^m\ 0^s.8$
μ_o	23 12 9	23 23 14
α	23 23 8.9	23 35 3.8
α_o	1 25 57	1 25 57
$\mu - \mu_o$	4 3.6	4 46.8
$\alpha - \alpha_o$	22 7 11.9	22 9 6.8
$t - t_o$	2 6 52	1 55 40
p_o	$287^s.9$	
ϕ	38° 57′	38° 57′
δ	5 51	5 7
ϵ	−1 2	−1 2
$\phi - \delta$	33 6	33 50
$\delta - \epsilon$	6 53	6 10
p_o	2.45927	2.45927
sec ϕ	.10919	.10919
sin $(\phi - \delta)$	9.73927	9.74568
sec $(\delta - \epsilon)$	.00314	.00252
sin $(t - t_o)$	9.72074	9.68443
t	2.02961	2.00109
	$1^m\ 47^s.1$	$1^m\ 40^s.3$
α	$23^h\ 23\ 8.9$	$23^h\ 35\ 3.8$
θ	23 24 56.0	23 36 44.1
μ	23 16 12.6	23 28 0.8
$\Delta\mu$	8 43.4	8 43.3
Mean $\Delta\mu$	8 43.4	

To put in evidence the divergence in the rigorous and approximate formulae for latitudes greater than 45°, the following reduction of an observation made at Göttingen (ϕ=51° 31′.8) is given below. The chronometer correction is computed from the approximate and rigorous formulae using seven place logarithms in both cases, and taking the observed and ephemeris data to the same number of decimal places.

GÖTTINGEN, SEPTEMBER 16, 1908.

	α Cygni		
μ	$20^h\ 19^m\ 50^s.0$	tan p_o	8.3156578
μ_o	20 17 15.3	tan δ	9.9233004
α	20 18 57.5	cos $(t_o - t)$	9.3280358
α_o	1 27 13.6	a	7.5669940
$\mu - \mu_o$	2 34.7	$1/(1-a)$	16050
$\alpha - \alpha_o$	18 51 43.9	tan p_o	8.3156578
$t - t_o$	$5^h\ 10^m\ 50^s.8$	sec δ	.1155341
	77° 42′ 42″	sin $(t_o - t)$	9.9899341 n
p_o	1° 11′ 6″	tan ξ	8.4227310 n
	$284^s.4$	sin δ	9.8077662
ϕ	51° 31′ 48″	tan x	8.2304972 n
δ	39 58 0	T	4.6856167
ϵ	−14′ 25″.82	log x''	3.5448805
$\phi - \delta$	11 33 48	x	−3506″.554
$\delta - \epsilon$	40 12 25.82	cos x	9.9999373

		$\tan \xi$	8.4227310	n
$p_\circ$	3.6300209	$\cos \delta$	9.8844659	
$\sec \phi$	.2061365	$\tan \phi$	.0998616	
$(\sin (\phi - \delta)$	9.3020082	$\sin m$	8.4069958	n
$\sec (\delta - \epsilon)$	.1170686	S	4.6855277	
$\sin (t - t_\circ)$	9.9899341	$\log m''$	3.7214681	
t	3.2451683	m	−5265″.845	
	°1758″.605	$x - m$	1759 .291	
	$1^m\ 57^s.240$		$1^m\ 57^s.286$	

The difference—to hundredths of a second—is $0^s.05$, and computing the term in the third power of $p_\circ$ for this star its value —to hundredths of a second—is $0^s.05$, thus accounting for the difference.

For approximate azimuth work with an engineer's transit, this method of obtaining the watch correction is especially well adapted to the precision of the instrument. An ordinary mean time watch may be roughly set to local sidereal time and then regarded as a sidereal time piece with a daily rate of $3^m\ 56^s.56$. The watch correction on local sidereal time may then be determined for a definite instant—the nearest even hour—and computed for any subsequent instant by applying the correction for rate. This correction is taken from Table III at the end of the *American Ephemeris and Nautical Almanac* with the elapsed interval as argument, and is additive. An example is given below, in which the correction is computed for 13 hrs. as indicated by the watch, showing that the roughly estimated local sidereal time was about 8^m too great when the watch was set.

WASHINGTON UNIVERSITY, MAY 7, 1905.

	α Virginis	π Hydrae
u	$13^h\ 28^m\ 33^s$	$14^h\ 10^m\ 11^s$
$u_\circ$	13 23 17	14 1 45
α	13 20 13.1	14 0 59 .8
$\alpha_\circ$	1 24 17	1 24 17
$u - u_\circ$	5 26	8 26
$\alpha - \alpha_\circ$	11 55 56	12 36 43
$t - t_\circ$	13 9 30	11 31 43
$p_\circ$	288″.5	
ϕ	38° 39′	38° 39′
δ	−10 40	−26 14
ϵ	1 12	1 12
$\phi - \delta$	49 19	64 55
$\delta - \epsilon$	11 52	−27 26
$p_\circ$	2.46015	2.46015
$\sec \phi$	.10736	.10736
$\sin (\phi - \delta)$	9.87985	9.95698
$\sec (\delta - \epsilon)$	.00938	.05181
$\sin (t - t_\circ)$	8.61741	9.09024
t	1.07415	1.66654
	−11″.9	46″.4

α	13 20 13.1	14 0 59.8
θ	13 20 1.2	14 1 46.2
u	13 28 33	14 10 11
Δu	− 8 31.8	− 8 24.8
Δ'''	4.7	11.5
Δu_{13}	− 8 36.5	− 8 36.3

$$-8^m\ 36^s.4$$

The azimuth of Polaris may be computed as follows. From the figure:

$$\sin a_\circ = \frac{\sin p_\circ}{\sin z_\circ} \sin t_\circ$$

and introducing

$$\sigma = -p_\circ \cos t_\circ + \frac{p_\circ^2}{2} \tan \phi \sin^2 t_\circ$$

$$\epsilon = -p_\circ \cos t_\circ + \frac{p_\circ^2}{2} \sin^2 t_\circ$$

We may write

$$\sin a_\circ = \sin p_\circ \sec (\phi - \sigma) \sin t_\circ$$

$$= \sin p_\circ \sec (\phi - \epsilon) \sin t_\circ$$

$$+ \frac{p_\circ^3}{2} \sec \phi \tan \phi (1 - \tan \phi) \sin^3 t_\circ$$

$$+ \text{terms of fourth and higher powers in } p_\circ.$$

Now $\sec \phi \tan \phi (1 - \tan \phi)$ vanishes for $\phi = 0$ and $\phi = 45$, and hence has a maximum between these values. This maximum, which lies near $\phi = 29°$, is less than .3 and hence for latitudes between 0° and 45° the corrective term in $p_\circ^3$ is less than 0′.005 and it remains less than this up to latitude 50°. For $\phi = 60°$ it reaches the value 0′.04 and beyond this latitude increases rapidly.

Hence, *for middle latitudes the approximate formula*

$$\sin a_\circ = \sin p_\circ \sec (\phi - \epsilon) \sin t_\circ$$

furnishes the azimuth of Polaris to within an error of 0′.005.

The example below shows how the mean time watch was corrected on local sidereal time and used for the azimuth determination. The inclination and collimation corrections were eliminated in the same way as in the time observations, first observing in the direct and then in the doubly reversed position of the instrument, keeping the plate level bubbles in the center in both positions.

WASHINGTON UNIVERSITY, MAY 28, 1909.

	u	Horizontal Circle ° ′ ″	° ′ ″
Mark		135 39.6 39.2	315 39.6 39.6
*	$14^h\ 24^m\ 56^s$	128 55.8 56.0	308 56.2 56.2
*	29 25	57.7 57.5	57.7 57.6
*	35 44	129 10.7 10.7	309 10.3 10.4
*	39 51	12.5 12.6	12.1 12.1
Mark		135 48.4 48.5	315 48.3 48.3
	$14^h\ 32^m\ 29^s.0$	$R_m = 135°\ 43'.94$	$R_* = 129°\ 4'.13$
Mark		135 48.1 48.0	315 48.0 47.9
*	15 24 49	129 26.3 26.4	309 26.1 26.0
*	27 12	27.4 27.3	26.8 26.7
*	33 20	21.0 21.2	21.6 21.6
*	36 23	22.2 22.2	22.6 22.7
Mark		135 38.6 38.5	315 38.9 39.0
	$15^h\ 30^m\ 26^s.0$	$R_m = 135°\ 43'.38$	$R_* = 129°\ 24'.23$

The watch correction on local sidereal time—determined on the same evening by the method explained above—was found be at 15 hrs.

$$\Delta u_{15} = 3^m\ 7^s.4.$$

This is reduced to the instants U_1 and U_2—the means of the times of setting on Polaris in the azimuth observations—by correcting Δu_{15} for the elapsed intervals between fifteen hours and U_1 and U_2. For U_1 the correction is negative and for U_2 positive. Those corrections are, of course, taken from the table for reducing a mean time interval to the corresponding sidereal interval —Table III

$$\Delta\mu_1 = \Delta\mu_{15} - \text{corr. for } (15 \text{ hrs.} - U_1)$$

$$\Delta\mu_2 = \Delta\mu_{15} + \text{corr. for } (U_2 - 15 \text{ hrs.}).$$

COMPUTATION.

U	$14^h\ 32^m\ 29^s.0$	$15^h\ 30^m\ 26^s.0$
Δu	3 2.9	3 12.4
θ	14 35 32	15 33 38
a_o	1 25 38	1 25 38
t_o	13 9 54	14 8 0
p_o	1° 10′.97	
ϕ	38 39	38 39
ϵ	1 7.5	1 0.2
$\phi - \epsilon$	37 31.5	37 38.8
$\sin p_o$	8.31477	8.31477
$\sec(\phi - \epsilon)$	.10068	.10139
$\sin t_o$	9.47754	9.72421
$\sin a_o$	7.89299	8.14037
a_o	0° 26′.87	0° 47′.50
$R_m - R_*$	6 39.81	6 19.15
A_m	7 6.68	7 6.65
Mean A_m	7° 6′.7 E. of N.	

If a greater degree of precision is desired than that indicated above the chronometer correction must be computed from the rigorous formulae on page (92)—an example of such a computation is given on page (96)—and the azimuth of Polaris from

$$\tan a_o = - \frac{\cot \delta_o \sec \phi \sin t_o}{1 - \cot \delta_o \tan \phi \cos t_o} .$$

The azimuth of the mark is then given by

$$A_m = a_o + R_m - R_* - i \cot z_o + I \cot Z \mp c \ (\operatorname{cosec} z_o - \operatorname{cosec} Z) + 0''.32 \frac{\cos \phi}{\sin z_o}$$

where I and Z refer to the mark.

Washington University,
St. Louis, Mo., Dec. 1, 1909.

THE CLOCK VAULT OF THE U. S. NAVAL OBSERVAVORY.

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[Communicated by the Superintendent U. S. Naval Observatory.]

For Popular Astronomy.

The clock vault of the U. S. Naval Observatory was designed and built in January and February, 1901, by Professor Milton Updegraff under the direction of Professor S. J. Brown, then astronomical director. It is located in the basement of the west observer's room near the six-inch transit circle and consequently is limited in size by this basement. The ground plan of this vault is shown in Figure *A*.

The vault is of a doubled walled construction having a so-called outer and inner vault; the walls being separated by an air space of about one foot. The outer vault is inclosed by brick walls nine inches thick, has a floor of concrete eight inches thick, while the ceiling is composed of six inches of mineral wool. The inner vault is built of wood and is about eight feet square with a height of seven feet. There is a door entering the outer vault from the basement and a set of double doors, forming an air-lock, lead from the outer to the inner vault. The three doors are never all opened at the same time.

The inner vault contains three substantial brick piers embedded in a footing of concrete upon which are mounted Riefler clocks Nos. 60, 70, and 151. There is also a low brick pier for

auxilliary apparatus which is used at present for a very sensitive Richard thermograph; this thermograph has a scale value of 10 mm. per degree centigrade and a sensitiveness of about 0°.01 is claimed for it by the makers. In each clock case is an accurate thermometer graduated to one-fifth of a degree Centigrade which is placed at the mean elevation of the pendulum, also each case contains the usual Riefler clock barometers. Max-

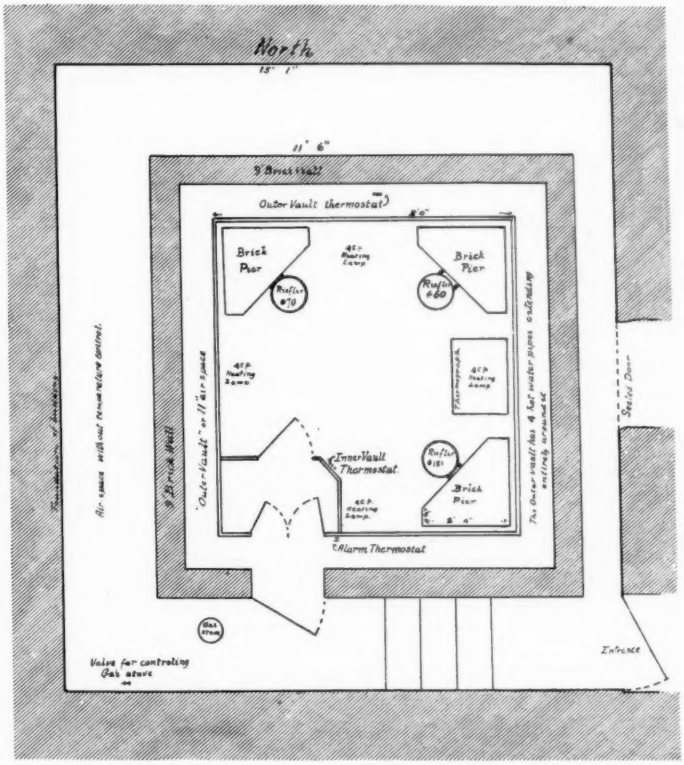


FIGURE A.—Plan of Vault.

imum-minum thermometers are mounted both in the inner and outer vaults.

The outer vault is heated by four hot water pipes running almost completely around it in the air space between the two vaults, and supplied from a gas water heater. The original gas stoves were used until December, 1908, when a new copper tube

gas water heater of better and more economical design was installed; and later there was provided efficient means of carrying off the waste products of combustion. The supply of gas is regulated by an electrically operated valve and thermostat placed in the air space between the inner and outer vaults and symmetrically situated with respect to the heating pipes. Before December, 1908, the thermostat used was of the well-known compound bar type which is designed and successfully used for commerical purposes, but is not of the proper type where accurate control of temperature is required.

During the latter part of 1908 a study was made of various forms of thermostats with a view to eliminating any appreciable changes for considerable periods of time. After investigating several forms and receiving valuable advice from Dr. Wolf of the Bureau of Standards, the type illustrated was designed.

The principle of this thermostat is the use of a liquid having a reasonably high coefficient of cubical expansion, to move a column of mercury into or away from contact with a platinum point. At first the liquid used was methyl alcohol because of its large expansion coefficient, but this was almost at once discarded on account of the apparent impossibility of preventing a leakage either through or around the inclosing column of mercury. At the suggestion of Dr. Wolf a purified kerosene was substituted and proved satisfactory in an experimental thermostat constructed of glass tubing sealed with melted shellac.

The construction of these thermostats shown in Figure B is very simple and needs no description except for a few practical points. The kerosene reservoir should be of sufficient size; in this case it is blown from glass tubing 16 mm. bore and 750 mm. long. The contact tube must not be too small, preferably not much under one millimeter bore, in thermostat No. 1 it is $0.^{mm}8$ and in No. 2 it is $3.^{mm}0$. The tube containing the kerosene must be completely filled in order to avoid any error due to varying barometric pressure. The mercury used was carefully cleaned with nitric acid and afterwards shaken together with ordinary kerosene for five minutes at intervals of a few hours for several days. A black sediment which is formed during this process can be allowed to settle or removed by filtration. It was thought best to have the tube for the kerosene sealed by the glass blower and the thermostats were filled by alternately heating and cooling, each time drawing in more kerosene. The column of mercury in the contact tube was set lower than the mercury-kerosene surface in order to prevent creepage of kerosene

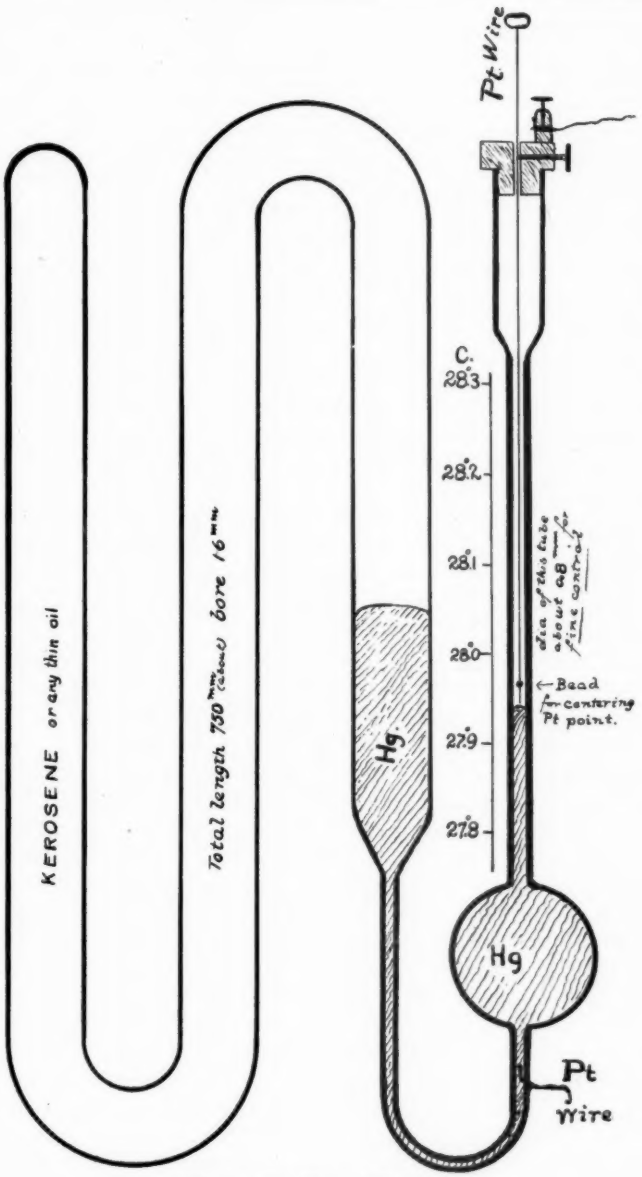


FIGURE B.—Plan of Thermostat.

between the mercury and the glass which otherwise is apt to occur for some days after the thermostat is set up.

On December 3, 1908, thermostat No. 1 was substituted for the compound bar thermostat in the outer vault. Some interesting results were obtained with this single control. A well marked heating and cooling period was shown on the thermograph records, amounting approximately to a tenth of a degree centigrade and with a period of between one and two hours corresponding to the period of heating by the gas water heater. Another temperature error was observed whenever there was a cold north wind blowing which seemed to relatively cool the thermostat with respect to the rest of the vault and thus raise the clock temperatures by about a tenth of a degree. During the spring months there was a slow and uniform rise in the clock cases of about one half degree. The records showed that the errors were due to a lag in the hot water heating system and to a varying distribution of the heat when the outside weather conditions varied.

It was deemed advisable to install a secondary or inner temperature control, with a sensitive and quick acting source of heat, and by this means to raise the temperature of the inner vault between ½° and 1° Centigrade. With this in view, four electric lights of four candle power each were placed in a symmetrical manner on the ceiling of the inner vault and provided with deep conical, metallic reflectors, throwing the radient heat toward the floor and shielding the clocks from direct radiation.

In May, 1908, thermostat No. 2 was substituted for No. 1 in the outer vault and the latter mounted in the inner vault at the mean elevation of the pendulums from the floor and thermally insulated from the walls so that it would have as nearly as possible the same temperature as the clock pendulums. Across the terminals of this thermostat is bridged an 800 ohm non-inductive resistance. The controlling current is supplied by four Gordon cells, grouped two in series, and operates a standard 150 ohm relay with heavy platinum contact points. The heating lamps are on the regular 110 volt alternating current lighting circuit of the observatory. This thermostat and relay operate between one and two thousand times a day, and the freedom from trouble at the contacts is very satisfactory; the platinum points on the relay showed scarcely a trace of wear at the end of six months, while the monthly cleaning of the mercury platinum contact appears almost unnecessary, probably because of the relatively low non-inductive resistance and the

high resistance of the relay. The mercury of the contact surface is cleaned by taking a few fine cotton covered wires, twisting them together, and running them down the contact tube into the mercury two or three times. This does not appreciably change the point of control, as in thermostat No. 1 two millimeters of mercury would have to be removed to change the point of control by a hundredth of a degree.

The old compound bar thermostat was placed in the outer vault and connected with an alarm on the watchman's desk in the main building. One contact was set a little above the highest and the other a little below the lowest normal temperature of the outer vault. This thermostat is to give warning when any part of the outer vault heating system gives out. In the west observer's room over the vault is placed a two candle power electric light connected on the same circuit as the heating lamps so that this pilot lamp operates in unison with them; in this way we can easily see the period of heating and cooling which varies from a few seconds to almost two minutes and is a valuable criterion of the temperatures. A much smaller disturbance than will affect either the thermometers or thermograph will stop the working of the pilot lamp. A person entering the vault in hot weather will turn off the heating lights in a few seconds, but in cold weather the lights, if off, are almost instantly turned on and may remain on for some time if much cold air has been carried in the vault on one's clothes.

When the secondary control was installed it was thought that probably an electric fan would be required to keep a uniform distribution of the heat in the vault. There does not seem to be much doubt that a fan would keep the air in motion and help to equalize the temperature in different parts of the vault and perhaps would be almost a necessity in some cases, particularly where the temperatures surrounding the vault varied considerably, but in this vault there has been no evidence in the past six months that fans are necessary. If it were desired to keep a very close temperature control for the use of uncompensated pendulums made of a pure unalloyed metal, a fan would probably be necessary or at least useful.

Since the installation of the secondary control, the temperatures have remained pratically constant; when no work is being done in the vault, the thermograph records from week to week appear to be straight lines, and the indices of the maximum-minum thermometer are not moved away from contact with the mercury column; the errors for periods of many weeks prob-

ably being only a few hundredths of a degree. Therefore it seems that no temperature terms can be used in the clock rates except upon the rare occasions when work is being done in the vault. It is thus hoped to reduce the errors of the clocks to the actual defects in the form and materials of which they are constructed or to causes unknown at present.

Washington, D. C.

ORIGIN OF THE LUNAR TERRESTRIAL SYSTEM BY CAPTURE, WITH FURTHER CONSIDERATIONS ON THE THEORY OF SATELLITES AND ON THE PHYSICAL CAUSE WHICH HAS DETERMINED THE DIRECTIONS OF THE ROTATIONS OF THE PLANETS ABOUT THEIR AXES.* III

T. J. J. SEE

VIII. On the true physical cause which determines the direction of planetary rotation.

It will be seen from the considerations already adduced, and examined with some care in the paper on the dynamical theory of the capture of satellites, that we explain the direction of rotation of the planets on the same principle by which we account for the direction of revolution of the satellites in their orbits. About each planet, within the Hill closed surface, and in the hour-glass surfaces which are not closed, waste matter from the nebulosity circulation about the Sun passes freely. As the hour-glass surface is not entirely closed for most of the particles, they naturally enter the region about the planet with a direct motion; and this same direction is naturally preserved when they fall down near the planet so as to pass within the closed surfaces. Therefore in general the satellites have direct revolutions in their orbits and the planets have direct rotations on their axes. Only crossing satellites, or those of irregular foreign origin have retrograde revolution: and most of these are destroyed. Those which fall into the planet under the secular effects of resistance check its rotation but slightly.

* From *Astro. Nach.* 4343.

Accordingly, while we admit Mr. Stratton's theory of planetary inversion under his postulated conditions, involving enormous duration of time, we deny that such history has been enacted in the solar system, unless possibly a slight effect of the kind has arisen in the systems of Uranus and Neptune, which are so remote from the Sun. In our view the direct rotations of the planets are inevitable consequences of the capture of nebulosity in the sheltered regions enclosed within the Hill closed surfaces. These closed spaces are regions into which waste material drifts as inevitably as water runs down hill. In these sheltered and sequestered regions systems of satellites develop, because the nebular vortices collected there circulate incessantly, and the waste nebulosity finally goes to the building up of the planets or the satellites. This conception of the sheltered vortex inside the Hill closed surfaces gives one a very clear idea of what takes place about the planets as they develop in the vaster extent of nebulosity circulating about the Sun.

As the planets originate at much greater distance from the Sun than they now are, we cannot assume that their rotations may not be partly fixed before they reach their present positions. Even retrograde rotation might be started in remote planets; and it may be that this still partially survives in the systems of Uranus and Neptune. Accident has much to do with the rotations of remote bodies, but in the inner parts of the system a more orderly development prevails, because the retrograde motions are largely obliterated, as we see in the actual solar system. Various causes have modified the rotation and axial tilt of the planets, but direct rotation is natural; while planetary inversion seldom if ever takes place.

IX. The Moon and other satellites, being small captured bodies, probably never had much rotation, but even this has been destroyed by resistance and tidal friction.

This proposition is almost obvious without elaborate analysis of the reasons why the smaller bodies have little rotational moment of momentum. For in coming together the elements of such a mass could hardly give it a rapid rotation about any axis, because the closed Hill surface about it is too small to give a large vortex for the collection of waste matter; and nothing but a large amount of this gathered rubbish revolving under strong central force could produce a rapid rotation in the planet formed by the subsequent condensation of the material. Thus owing to the small size of the Hill closed surface,

and the feeble central attraction—both being due to the smallness of the mass—the rotation of a small body like the Moon can never be very rapid. Accordingly neither the terrestrial Moon nor any of the other satellites of the solar system ever had rapid axial rotation, and the same remark applies to the planet Mercury. Yet what little rotations the Moon, the satellites of Jupiter, Saturn, and other planets may have had, have been exhausted by subsequent resistance, and especially by the tidal friction of the planets about which they revolve. It is not surprising, therefore, that they show only one face towards their several planets. The result has long been regarded as probable; but previous writers, being unaware of the causes which determine rotation and that the satellites were captured, have perhaps overrated the chances of primitive rapid rotation, and made the destruction of the axial rotations seem more important than it really is. For as the Earth has been thought to have rotated in about $2^h\ 41^m$, according to Darwin, it might naturally have been supposed that the rotation period of the Moon also was at one time comparatively short. If the present views are correct, this has never been the case; and although tidal friction has been the main cause working to exhaust the rotations, there never was much rotation to be destroyed. The force of this argument becomes more apparent by remembering that if the Moon is a captured body, there is no good reason to suppose that the Earth ever did rotate much more rapidly than it does at present.

Problems such as the loss of the atmospheres of the Moon and of other satellites also take on a new aspect; for we have no reason to believe any sensible atmosphere ever existed about these small captured bodies. Nor is it probable that there is snow or ice on the Moon's surface, as many writers have supposed. Whether the large craters can have been formed by the impact of small satellites upon a heated and molten surface, as the geologist C. K. Gilbert believed, must be left to the future to determine.

The Moon being in the present hypothesis a planet and not a portion of the Earth, we have to give up most of the supposed analogy between terrestrial and lunar volcanoes and mountains. The mountains on the Moon apparently were formed before it was captured by the Earth. And therefore while we lose by giving up the assumed analogy with the Earth, we gain by our new privilege of studying at close range a planet from the celestial spaces formed quite independently of the

Earth. If this view be correct, there will be a considerable advantage to science; for we never expected that this privilege of such close telescopic inspection of another planet would be given to the inhabitants of our terrestrial globe.

In this connection I may say that on one or two occasions when the seeing was at its best during the observations of the planet Mercury at Washington in 1901 and 1902, I believed I obtained glimpses of the planet's surface of the same type as that of the Moon. It may well be that these brief glimpses gained at moments of best seeing, supported as they are by the evidence of photometric measures, showing that the planet has a rough surface, rest on a more substantial basis than any one heretofore has ventured to believe. One gets the impression that the origin of the Moon and of the planet Mercury is essentially the same, and that at one time both revolved in the planetary spaces between the present orbits of Mars and Jupiter.

X. The terrestrial spheroid itself shows little if any evidence of having had more rapid rotation in former times.

The theory that the Moon is a captured body carries with it several important corollaries, which deserve careful consideration. Foremost among these is the question whether the Earth rotated much more rapidly in former times than it does now. It has long been believed that the Earth once had a much more rapid rotation than at present, and tables of the changes in the Earth's figure and physical constitution arising from such supposed rapid rotation have been calculated and published in various works on geology and physics. But it is a remarkable fact that if we examine this work carefully, we shall find that it rests not on observed phenomena, but on Darwin's celebrated papers on the origin of the lunar terrestrial system, which have been analyzed above. On the other hand, the terrestrial spheroid itself gives little if any evidence of more rapid rotation in former times. No well established facts in geology, physics, or geodesy support such a view.

It is true that the changes in the rate of rotation of our planet might be supposed to be so slow that all traces of the former state of the Earth would have been wholly obliterated by the transformations which have intervened; yet it is not certain that this would be so, and it seems more probable that the greater oblateness once existing would have left sensible traces of incomplete adjustment to modern conditions. So far as may be judged from accurate measurements of gravity, and

from many trigonometric measurements carried out in all latitudes and in both hemispheres, by various geodetic surveys, no certain inequalities pointing to a former rapid rotation of the Earth have been discovered. The inequalities found all seem to be local, and connected with the formation of the continents, which owe their elevation and outlines to the secular leakage of the oceans (cf. Further Researches on the Physics of the Earth, and especially on the Folding of Mountain Ranges and the Uplift of Plateaus and Continents produced by Movements of Lava beneath the Crust arising from the Secular Leakage of the Ocean Bottoms, Proc. Am. Philosophical Society, Philadelphia, No. 189, 1908).

In his valuable work on Tides and kindred Phenomena in the Solar System, pp. 300-304. Sir George Darwin discusses this question of the Earth's adjustment with some care. He admits that Lord Kelvin did not share his view that the Earth had adjusted its figure to suit its rate of rotation. He says Lord Kelvin held "that the fact that the average figure of the Earth corresponds with the actual length of the day proves that the planet was consolidated at a time when the rotation was but little more rapid than it is now." And adds: "The difference between us is, however, only of degree, for he considers that the power of adjustment is slight, whilst I hold that it would be sufficient to bring about a considerable change of shape within the period comprised in geological history."

Sir George Darwin then proceeds to analyze four classes of facts derived from observation,—gravity, the ellipticity of the Earth, the lunar inequality depending on the Earth's figure, and the precession and nutation of the Earth's axis—and says that they are so intimately intertwined that one of them cannot be touched without affecting the others. In conclusion he adds: Edouard Roche, a French mathematician, has shown that if the Earth is perfectly plastic, so that each layer is exactly of the proper shape for the existing rotation, it is not possible to adjust the unknown law of internal density so as to make the values of all these elements accord with observation. If the density be assumed such as to fit one of the data, it will produce a disagreement with observation in others. If, however, the hypothesis be abandoned that the internal strata all have the proper shapes, and if it be granted that they are a little more flattened than is due to the present rate of rotation the data are harmonized together; and this is just what would be expected according to the theory of tidal friction. But it would not be right to attach great weight to this argument, for the absence of harmony is so minute that it might be plausibly explained by errors in the numerical data of observation. I notice, however, that the most competent judges of this intricate subject are disposed to regard the discrepancy as a reality."

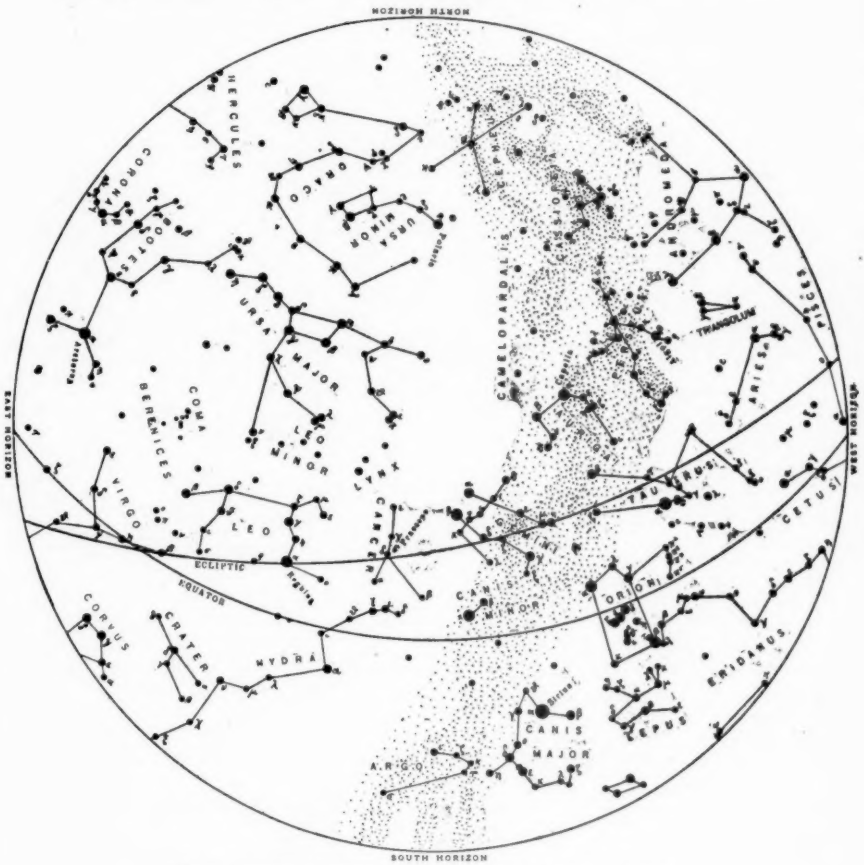
Mare Island, California.

(To be concluded).

PLANET NOTES FOR MARCH, 1910.

Mercury during this month is passing around to the farther side of the Sun and so cannot readily be seen. It will be at aphelion March 2.

Venus having passed between the Earth and Sun on February 11 is now morning star and will attain her greatest brilliancy again on March 18.



THE CONSTELLATIONS AT 9:00 P. M., MARCH 1, 1910.

Mars may be seen toward the southwest during the early evening. His course is eastward through Taurus, passing south of the Pleiades. The planet will be directly south of the Pleiades March 10-12.

Jupiter will be at opposition March 30, and so may be seen during most of the night. The planet is in the constellation Virgo, northwest of the star Spica and is much brighter than that star.

Saturn may be seen toward the southwest in the early evening but at too low an altitude for good observing.

Uranus may be seen in the morning toward the southeast but is not in favorable position for study.

Neptune is in the constellation Gemini in good position for observation in the first half of the night. To recognize it one must use a telescope of sufficient power to show the disk of the planet or with a smaller telescope must use a star chart showing all the stars in the vicinity down to the ninth magnitude.

Occultations visible at Washington.

Date 1910	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	Angle from N. °	EMERSION. Washington M.T. h m	Angle from N °	Duration. h m
Mar. 1	26 Librae	6.3	15 06	162	16 14	266	1 08
1	28 Librae	6.2	19 44	62	20 37	336	0 53
2	10 G. Scorpii	5.9	12 10	189	12 28	223	0 18
3	26 Ophiuchi	5.8	19 23	161	20 10	223	0 47
5	ϕ Ophiuchi	3.3	15 31	145	16 20	235	0 49
16	τ Tauri	4.5	7 26	77	8 40	262	1 14
18	37 Geminorum	5.7	13 27	146	14 03	233	0 36
22	46 Leonis	5.8	14 30	64	15 06	355	0 36
29	41 Librae	5.3	9 13	68	9 53	345	0 40
29	κ Librae	5.0	10 53	72	11 41	348	0 48
31	136 G. Ophiuchi	6.3	13 06	140	14 11	260	1 05
31	151 G. Ophiuchi	6.0	16 08	132	17 29	255	1 21

COMET AND ASTEROID NOTES.

Daniel's Comet *c* 1909.—Daniel's comet is not fading as rapidly in brightness as one would expect from the ephemerides. On January 15 it was easily picked up with our five-inch finder, and was even easier to observe with the sixteen-inch telescope than when it was first seen. It is not following closely the published ephemerides, and it seems probable that the orbit will turn out to be elliptic. The following parabolic elements have come to hand since the January number of POPULAR ASTRONOMY went to press:

Computer	Russell (Princeton)	Ebell (Kiel)	Krassowski (Nice)
T	1909 Dec. 1.74722 (Gr.)	Nov. 27.6694 (Berlin)	Nov. 29.77 (Paris)
ω	5° 30′ 57″	2° 31′.28	10° 52′.1 }
Ω	73 31 29	73 27 .13	68 57 .6 } 1909.0
i	26 50 28	26 36 .38	1 14 .4 }
log q	0.194392	0.19114	0.16143
Dates of Obs.	Dec. 7, 8, 9	Dec. 8, 10, 13	Dec. 7, 10, 14

From observations at Northfield with the sixteen-inch telescope on the dates Dec. 8, 18 and 28, the writer (H. C. Wilson) and Mr. C. H. Gingrich have computed the following parabolic elements, which do not represent the middle place satisfactorily in longitude, leaving a residual of 1′ 36″, but which represent observations made in January considerably better than the elements given above. Owing to the pressure of college duties we have not found time to try an elliptic orbit.

ELEMENTS OF COMET *e* 1909, (DANIEL).

Computers: Wilson and Gingrich

T	1909 Nov. 21.52427	
ω	357° 43′ 28″	1909.0
Ω	73 21 13	1909.0
i	26 11 57	1909.0
log q	0.182149	

EPHEMERIS.

Greenwich Midnight 1910	α h	α m	α s	δ °	δ ′	δ ″	log r	log Δ	Br.
Jan. 31	6	30	46.7	+57	34	44	0.2568	9.9973	0.24
Feb. 4	6	35	09.3	57	38	33	0.2638	0.0186	0.21
8	6	40	05.7	57	35	06	0.2709	0.0397	0.19
12	6	45	31.9	57	25	02	0.2780	0.0605	0.16
16	6	51	25.0	57	09	15	0.2853	0.0810	0.14
20	6	59	42.1	56	48	56	0.2925	0.1012	0.13
24	7	04	17.8	56	24	35	0.2998	0.1211	0.11
28	7	11	08.6	55	56	56	0.3572	0.1406	0.10
Mar. 4	7	18	13.8	55	26	34	0.3146	0.1596	0.09

The brightness December 6 is taken as unity.

Notes on the Appearance of Halley's Comet.—Professor E. E. Barnard of the Yerkes Observatory was the first astronomer to see Halley's comet at this apparition. The comet was photographed first by Wolf at Heidelberg on the night of Sept. 11, 1909, but it was not detected visually, so far as we are aware, until Professor Barnard picked it up with the forty-inch Yerkes telescope on Sept. 17. The following notes made by Professor Barnard at the time of his observations will be of value in the study of the changes in appearance of the comet when far off from the Sun.

1909 Sept. 17. The magnitude was estimated 15½; the diameter 5″±. Measured diameter 7″.2. There was possibly a faint nucleus of the 15th magnitude, or an indefinite brightening in the middle. It appeared as a "fleck" of light surrounded by a faint nebulosity for a few seconds. A little later it was quite easy to observe and was estimated to be 15th magnitude. Sky good, seeing good.

Sept. 24. Measured diameter of the full extent of the nebulosity = 11″.1. This nebulosity was extremely faint. There was a brighter "fleck" of light in the middle some 2″ diameter—possibly a nucleus. With 700 diameters the comet was quite easy, the brighter part about 15th magnitude. The whole comet would not be fainter than 15½ magnitude. With this power it was quite noticeable, but there was no nucleus, only an indefinite brightening in the middle.

Sept. 26. It was much brighter and seemed to be about 14 or 14½ magnitude at faintest; measured diameter 9″.5; gradually brighter in the middle. The "fleck" of light seemed to have disappeared—the comet was more generally condensed and seemed larger. No definite nucleus. No elongation and no definite boundary.

Oct. 17. The comet was fairly bright, about 13th magnitude, some 10″± in diameter, and brighter in the middle. Seeing bad.

Oct. 19. Diameter 15″±. It was bright in the middle to an indefinite "fleck of light." Estimated to be 13th magnitude—sky very thick.

Oct. 26. Nearly full moon. In the first observations the comet was well seen, but faint, on the moon-lit sky. After moon-set the comet was pretty bright in the middle to nearly a nucleus. Sky fairly clear.

Nov. 14. Estimated magnitude 13—much brighter in the middle to almost a nucleus. Sky very transparent. During moments of steadiness there was apparently a minute point of light in the nebulosity. The comet was round, with no signs of a tail. Measured diameter = 11″.6.

Nov. 28. Comet bright in nearly full moon-lit sky.

Nov. 30. Before moonrise, though the comet was very low, it could be seen fairly well with the four-inch finder of the forty-inch telescope. In the large telescope it was about 11^m. There was almost a nucleus. The measured diameter —the extreme extent of the faint nebulosity of the comet—was 41″. The brightest portion was almost 7″ diameter; and what was perhaps an ill-defined nucleus, was something like one or two seconds in diameter.

It may be interesting to see what the various measures and estimates of the diameter of the comet given in this paper represent. The following table contains these values. From the nature of the case they must be discordant, but I think the mean will not be very far out. I do not think the real diameter will greatly exceed this or it would be indicated on long-exposure photographs.

OBSERVED DIAMETERS OF HALLEY'S COMET.

		″	Miles	Weight
1909	Sept. 17	7.2	10800	5
	24	11.1	15900	5
	26	9.5	13400	5
	Oct. 17	10.0±	11200	1
	19	15.0±	16400	1
	26	15.0±	15100	1
	Nov. 14	11.6	9200	5
Mean	Oct. 21		12600	23

Which makes its diameter at these observations about one and one-half times that the Earth. Of course the diameter of the comet, when at its brightest, will vastly exceed this value.

Yerkes Observatory, Nov. 18, 1909.

Near Approach of Halley's Comet to Venus. I do not know that it has been noticed, as yet, that Halley's comet will, on the way out from perihelion, make as near an approach to Venus as that which it makes to the Earth. The figures are as follows:

Heliocentric conjunction in longitude, May 1.82, G. M. T.

Helioc.	Longitude	Latitude	Radius vector
Comet	269° 44′	+9° 44′	0.646
Venus	269 44	−0 48	0.727

The distance of the planet from the prolonged radius vector of the comet is probably too great to involve it in the tail, and the appearance of the comet, as seen from Venus, if there should be any one to see it, would be very fine.

The spectacle will be interesting, as seen from here. The approximate geocentric positions will be, on the morning of May 2,

	α	δ
Comet	23^h 55^m	+8° 20′
Venus	23 43	−2 40

As Venus is very nearly of the same size as the Earth, a good idea may be gained, from the view, of the relative dimensions of the comet and of our own planet. The Moon will be up, but in the last quarter.

It may be well to remark that the poor showing made by the comet in 1835 was due rather to the relative positions of the Earth, Sun, and comet than to any loss in the comet itself. It passed us about the middle of October on the way into perihelion, but at the time of perihelion and afterward was very far away, and on the other side of the Sun, to which latter circumstance its failure in the way of tail may well have been due, as the tail was turned nearly away from us. At the time for the best development of it, the end of November and beginning of December, the comet was within a few degrees of the Sun, as seen from the Earth, and on the other side.

There seems, therefore, to be no special reason to expect the appearance of Halley this time to be inferior to that of 1759, as the circumstances now are remarkably favorable, except those concerning the Moon.

New York. GEO. M. SEARLE.

Halley's Comet.—The following telegram has been received at this observatory from Professor E. B. Frost, director of the Yerkes observatory :— "Prismatic camera shows light of Halley's comet to be now largely due to third cyanogen band. Frost, Parkhurst."

Astronomical Bulletin, No. 378,
Harvard College Observatory,
Cambridge, Mass., Dec. 31, 1909.

Halley's Comet will brighten rapidly during February and March, and would undoubtedly become visible to the naked eye were it not coming nearer into line with the Sun all the time, so that in March it will be in deep twilight. The comet is farther away than the Sun, and will come into conjunction with it on March 25. At the time of conjunction the comet will be about six degrees north of the Sun. After conjunction it will come rapidly out of the morning twilight, and soon become visible to the naked eye toward the east for a short time before sunrise on each morning. Its course among the stars during March will extend only a little way to the west of the line drawn in the little chart on page 50 of the January number of POPULAR ASTRONOMY. As at that time these stars will all be invisible in the twilight, the map will be of little use.

During December the comet became bright enough to be seen with small telescopes. Several have reported views of it with four and three-inch telescopes. Professor Philip Fox, director of Dearborn Observatory saw it during the total eclipse of the Moon on the morning of Nov. 27 with the 3¾-inch finder of the 18-inch telescope.

According to the Harvard Astronomical Bulletin No. 379, Professor E. E. Barnard photographed the comet with the Bruce telescope on Dec. 29, and finds upon the photograph a very faint tail in position angle 69°, with a length of 10′. The tail was very slender and straight.

Corrected Elements of Halley's Comet.—The following elements of Halley's comet are given in *A. N.* 4379 by Mr. A. C. D. Crommelin of the Royal Observatory at Greenwich. The time of perihelion passage T has been corrected by means of the Greenwich observations of the comet from Sept. 9, 1909 to Nov. 6, 1909.

$T = 1910$ April 19.67 Gr. M. T.
$\omega = 111°\ 42'\ 16''$
$\upsilon = 57\ 16\ 12$ } 1910.0
$i = 162\ 12\ 42$

$e = 0.967281$
$\mu = 46''.669$
$\log a = 1.253986$
$\log q = 9.768786$

Halley's Comet in Three-Inch Telescope. The comet was first looked for on the morning of Nov. 17, and again on the 26th, during totality of Moon eclipse, but nothing definite was seen, though being an ideal night. Cloudy weather prevented any further observations until Dec. 19, when it was probably sighted while identifying the field for a more detailed look after the Moon had set, but clouds prevented a definite identification. But conditions were better on Dec. 31.27, and it was easily picked up being very faint and diffuse, and appearing below the eleventh magnitude, nearly at the limit of vision. Since then, it has been observed on the nights of Jan. 8, 9 and 10, and is rapidly getting brighter, with a strong central condensation amounting to a nucleus, but nearly round with a power of 27 on three-inch.

Cleveland, Ohio, Jan. 10, 1910. WM. E. SPERRA.

Halley's Comet. I had a fine view of Halley's comet on the evening of December 4th, and also on the following night Dec. 5th. I could easily follow it among the telescopic stars of which there were a number in the field of my 4½-inch refractor. I have made inquiries but have not heard of another instrument of that size that had reached it at that date. It would be interesting to amateurs to know the earliest date the comet was seen with small telescopes.

Charlestown, Indiana. WILLIS L. BARNES.

Ephemeris of Halley's Comet.

[Computed at Goodsell Observatory from the elements given on p. 50.]

Greenwich Midnight 1910	α 1910.0 h	m	s	δ 1910.0 °	′	″	log r	log Δ	Br.
Feb. 3	0	59	44.3	+8	14	54	0.1914	0.2398	17
4	0	58	23.8	8	12	33			
5	0	57	04.6	8	10	22			
6	0	55	48.2	8	08	22			
7	0	54	33.9	8	06	30	0.1743	0.2489	17
8	0	53	21.6	8	04	47			
9	0	52	11.3	8	03	13			
10	0	51	02.9	8	01	47			
11	0	49	56.2	8	00	29	0.1564	0.2570	18
12	0	48	51.2	7	59	19			
13	0	47	47.8	7	58	17			
14	0	46	46.0	7	57	22			
15	0	45	45.7	7	56	33	0.1375	0.2639	19
16	0	44	46.8	7	55	51			
17	0	43	49.2	7	55	15			
18	0	42	52.9	7	54	45			
19	0	41	57.7	7	54	20	0.1177	0.2696	20
20	0	41	03.5	7	54	01			
21	0	40	10.3	7	53	47			
22	0	39	18.1	7	53	38			
23	0	38	26.7	7	53	33	0.0968	0.2740	22
24	0	37	36.2	7	53	33			
25	0	36	46.4	7	53	37			
26	0	35	57.3	7	53	45			
27	0	35	08.9	7	53	56	0.0748	0.2769	24
28	0	34	21.0	7	54	10			
Mar. 1	0	33	33.6	7	54	28			
2	0	32	46.7	7	54	48			
3	0	32	00.1	7	55	10	0.0515	0.2782	27
4	0	31	13.9	7	55	35			
5	0	30	27.9	7	56	02			
6	0	29	42.1	+7	56	30			

Ephemeris of Halley's Comet.—Continued.

Greenwich Midnight 1910	α 1910.0 h m s	δ 1910.0 ° ′ ″	log r	log Δ	Br.
Mar. 7	0 28 56.5	+7 57 00	0.0270	0.2779	30
8	0 28 10.9	7 57 31			
9	0 27 25.4	7 58 03			
10	0 26 39.8	7 58 36			
11	0 25 54.2	7 59 09	0 0012	0.2758	34
12	0 25 08.4	7 59 42			
13	0 24 22.4	8 00 15			
14	0 23 36.1	8 00 47			
15	0 22 49.5	8 01 18	9.9740	0.2717	39
16	0 22 02.6	8 01 48			
17	0 21 15.2	8 02 16			
18	0 20 27.4	8 02 43			
19	0 19 39.1	8 03 07	9.9457	0.2652	46
20	0 18 50.2	8 03 29			
21	0 18 00.7	8 03 48			
22	0 17 10.6	8 04 05			
23	0 16 19.9	8 04 18	9.9164	0.2563	55
24	0 15 28.5	8 04 28			
25	0 14 36.4	8 04 33			
26	0 13 43.6	8 04 35			
27	0 12 50.1	8 04 33	9.8865	0.2443	66
28	0 11 55.8	8 04 26			
29	0 11 00.9	8 04 14			
30	0 10 05.4	8 03 58			
31	0 9 09.2	+8 03 37	9.8569	0.2289	82

New Comet *a* 1910.—Just as the last copy for this number of POPULAR ASTRONOMY must be handed in, a new great comet has appeared in the western evening sky, which challenges the attention of all beholders and promises to rival the great comets of 1881 and 1882. No elements are at hand and the comet has been so close to the Sun for the last few days that no accurate measures of its position could be obtained. Its course appears to be northeastward so that it will be visible for some time in the evening sky, and as it is conspicuous to the naked eye soon after sunset, an ephemeris is at present unnecessary.

The first announcement of the comet came from Johannesburg, South Africa, where the comet was seen five or ten degree S S W of the Sun at and after sunrise on the morning of January 17. It is reported to have been seen two mornings earlier in the Orange Free State. The comet was observed in daylight at Lick Observatory by Wright. The spectrum of the nucleus was found to be continuous with a bright sodium line extending into the comet. At Northfield the comet was seen first on the evening of Jan. 20. The tail was five or six degrees long and nearly straight.

If the comet's course does not curve too rapidly, it will pass through Pegasus into Andromeda in the next two weeks. The following approximate positions are all that are at hand at the time of writing (Jan. 21) :

Greenwich mean time	α	δ	Observer	Place
Jan. 16.8119	19h 50m 28s	−25° 9′ 24″	Ainnes	Johannesburg
20.5	20 46.2	−12 57	Wilson	Northfield
21.5	20 54.7	−10 25	Wilson	Northfield

Elements of Comet *a* 1909.—A cablegram received from Kiel, Germany, through the courtesy of Harvard College Observatory, Jan. 23, gives the following approximate elements and ephemeris of the new comet, computed by Ekbold :

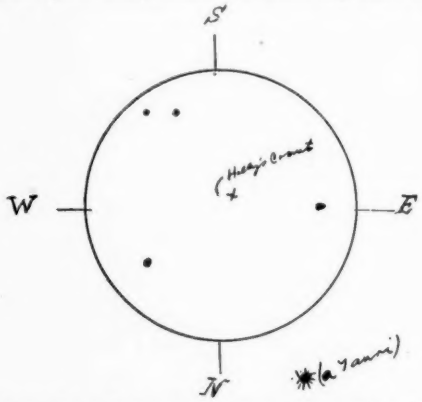
Time of perihelion passage	$T = 1910$ Jan. 17.38
Node to perihelion	$\omega = 263°\ 06'$
Longitude of ascending node	$\Omega = 8\ 56$
Inclination to ecliptic	$i = 62\ 16$
Perihelion distance	$q = 0.041$

EPHEMERIS FOR BERLIN NOON.

	R. A.	Decl.	Brightness
Jan. 22	$20^h\ 58^m$	$-\ 8°\ 56'$	1.00
26	21 25	$+\ 0\ 20$	
30	21 47	$+\ 7\ 45$	
Feb. 3	22 06	$+13\ 50$	0.12

On the night of Jan. 23 the comet was conspicuous in the west at 6:15, nucleus first magnitude, tail about 10° long and curved slightly to the left. A shorter faint tail about 1° long inclined much more toward the left.

Halley's Comet Observed.—On November 30th about 8:30 P. M. (Rocky Mountain time) while searching with a 6½-inch reflector the region close to and a little south of Aldebaran, where Halley's comet is supposed to be, I found what surely must be that object. It was very faint, practically round, with a distinct brightness or condensation in the center, and about ½° south and a few minutes west of Aldebaran. This object was distinctly seen by another person even more inexperienced in observing than myself, who was



with me at the time. I can find no nebula near this position in Herschel's New General Catalogue (rev. by Dreyer.). I used powers of about 40 and 70. The sky glow from the rising Moon soon rendered the comet invisible.

As it might be of interest, I will mention that the low power eyepiece I use (giving a power of about 40) is an old two-inch microscope eyepiece which I have fitted to the focussing tube of the telescope with an "adapter" made of moistened card board wrapped around the eyepiece so as to make a snug fit. If any one has an old microscope eyepiece, try it. It works finely!

Butte, Montana. CHAS. M. PALMER.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

Z Persei		ST Persei		RT Persei		RY Aurigæ		RW Monoc.	
d	h	d	h	d	h	d	h	d	h
Mar. 2	0	Mar. 18	18	Mar. 28	12	Mar. 1	22	Mar. 7	12
5	1	21	9	29	8	4	16	9	10
8	3	24	1	30	5	7	9	11	8
11	4	26	17	30	1	10	2	13	6
14	5	29	8	31	21	12	20	15	3
17	7	RX Cephei				15	13	17	1
20	8	Mar. 8	4	λ Tauri		18	7	18	23
23	10			Mar. 4	18	21	0	20	21
26	11	Algol		8	17	23	18	22	18
29	12	Mar. 3	16	12	16	26	11	24	16
		6	13	16	14	29	5	26	14
RY Persei		9	10	20	13	31	22	28	12
Mar. 7	10	12	7	24	12			30	9
14	6	15	4	28	11	RZ Aurigæ		RX Geminorum	
21	3	18	0			Mar. 3	2	Mar. 8	5
28	0	20	21	RW Tauri		6	3	20	10
		23	18	Mar. 1	9	9	3		
		26	15	4	3	12	4	RU Monoc.	
		29	12	6	22	15	4	Mar. 1	1
RZ Cassiop.				9	16	18	4	1	23
Feb. 1	9			12	11	21	5	2	20
2	13			15	5	24	5	3	18
3	18	RT Persei		18	0	27	6	4	15
4	23	Mar. 1	7	20	18	30	7	5	13
6	3	2	4	23	13			6	10
7	8	3	0	26	7	RW Geminorum		7	8
8	13	3	21	29	2	Mar. 1	12	8	5
9	17	4	17	31	20	4	9	9	3
10	22	5	13			7	5	10	0
12	3	6	10	RV Persei		10	2	10	22
13	7½	7	6	Mar. 1	4	12	23	11	19
14	12	8	3	3	3	15	20	12	17
15	17	8	23	5	3	18	16	13	14
16	22	9	19	7	2	21	13	14	12
18	2	10	16	9	1	24	10	15	9
19	7	11	12	11	1	27	7	16	7
20	12	12	8	13	0	30	4	17	4
21	16	13	5	14	23	U Columbæ		18	2
22	21	14	22	16	23	Mar. 2	19	18	23
24	2	15	18	18	22	5	15	19	21
25	6	16	14	20	21	8	10	20	18
26	11	17	11	22	21	11	5	21	16
27	16	18	7	24	20	14	0	22	13
28	20	19	4	26	20	16	19	23	11
30	1	20	0	28	19	19	15	24	8
31	6	20	20	30	18	22	10	25	6
		21	17			25	5	26	3
ST Persei		22	13	RW Persei		28	0	27	6
Mar. 2	21	23	9	Mar. 6	20	30	19	27	1
5	12	24	6	20	0			27	22
8	4	25	2			RW Monoc.		28	20
10	19	25	23	RS Cephei		Mar. 1	19	29	17
13	11	26	19	Mar. 11	16	3	17	30	15
16	2	27	15	24	2	5	15	31	12

Minima of Variable Stars of the Algol Type.—Continued.

RY Geminorum			V Puppis			Y Leonis			Z Draconis			SX Ophiuchi		
	d	h		d	h		d	h		d	h		d	h
Mar.	9	18	Mar.	15	3	Mar.	8	1	Mar.	11	22	Mar.	8	19
	19	2		16	14		9	17		13	6		10	20
	28	9		18	1		11	10		14	15		12	22
				19	12		13	2		15	24		14	23
R Canis Maj.				20	23		14	19		17	8		17	1
Mar.	2	0		22	9½		16	11		18	17		19	2
	3	3		23	20		18	4		20	1		21	4
	4	6		25	7		19	20		21	10		23	5
	5	9		26	18		21	13		22	18½		25	7
	6	13		28	5		23	5		24	3		27	8
	7	16		29	16		24	22		25	12		29	10
	8	19		31	3		26	14		26	20		31	11
	9	22					28	7		28	5			
	11	2	X Carinæ				29	23		29	13	SW Ophiuchi		
	12	5	Mar.	1	9		31	16		30	22	Mar.	2	18
	13	8		2	11	RR Velorum			SS Centauri				5	5
	14	11		3	13	Mar.	1	2	Mar.	2	20		7	15½
	15	15		4	15		2	23		4	8		10	2
	16	18		5	17		4	19		7	19		12	13
	17	21		6	19		6	16		9	7		15	0
	19	1		7	21		8	12		11	18		17	10
	20	4		8	23		10	9		14	6		19	21
	21	7		10	1		12	5		16	17		22	8
	22	10		11	3		14	2		19	5		24	18
	23	14		12	5		15	22		21	16		27	5
	24	17		13	7		17	19		24	4		29	16
	25	20		14	9		17	20		26	15			
	26	23		15	11		19	15		29	2	R Aræ		
	28	3		16	13		21	12		31	13	Mar.	2	13
	29	6		17	15		23	8					6	23
	30	9		18	17		25	5	δ Libræ				11	9
	31	12		19	19		27	1	Mar.	1	22		15	20
				20	21		28	22		4	6		20	6
Y Camelop.				21	22		30	18		6	14		24	16
Mar.	1	15		23	*0	SS Carinae				8	22		29	2
	4	22		24	2	Mar.	4	4		11	6	U Ophiuchi		
	8	6		25	4		7	12		13	14	Mar.	1	1
	11	13		26	7		10	19		15	22		1	21
	14	20		27	9		14	2		18	5		2	17
	18	4		28	11		17	9		20	13		3	13
	21	11		29	13		20	16		22	21		4	9
	24	18		30	15		23	24		25	5		5	6
	28	2		31	17		27	7		27	13		6	2
							30	14		29	21		6	22
RR Puppis			S Cancri			RW Urs. Maj.							7	18
Mar.	1	1	Mar.	5	19	Mar.	7	6	U Coronæ				8	14
	7	11		15	7		14	14	Mar.	2	0		9	10
	13	22		24	18		21	22		5	11		10	6
	20	8	S Velorum				29	6		8	22		11	2
	26	18	Mar.	4	14	Z Draconis				12	9		11	23
V Puppis				10	12	Mar.	1	1		16	20		12	19
Mar.	2	1		16	11		2	10		19	7		13	15
	3	12		22	9		3	18		22	18		14	11
	4	23		28	7		5	3		26	4		15	7
	6	10	Y Leonis				6	12		29	15		16	3
	7	20	Mar.	1	7		7	20	SX Ophiuchi				16	23
	9	7		2	24		9	5	Mar.	2	14		17	19
	10	18		4	16		10	13		4	16		18	16
	12	5		6	8½					6	17		19	12
	13	16											20	8

Minima of Variable Stars of the Algol Type.—Continued.

U Ophiuchi

	d	h
Mar.	21	4
	22	0
	22	20
	23	16
	24	12
	25	9
	26	5
	27	1
	27	21
	28	17
	29	13
	30	9
	31	6

SZ Herculis

Mar.	1	11
	2	7
	3	3
	3	22
	4	18
	5	13
	6	9
	7	5
	8	0
	8	20
	9	16
	10	11
	11	7
	12	3
	12	22
	13	18
	14	13
	15	9
	16	5
	17	0
	17	20
	18	16
	19	11
	20	7
	21	2½
	21	22
	22	18
	23	14
	24	9
	25	5
	26	0
	27	16
	28	11
	29	7
	30	2
	30	22
	31	18

Z Herculis

Mar.	1	3
	5	2
	9	2
	13	2
	17	2
	21	2
	25	2
	29	1

RS Sagittarii

	d	h
Mar.	2	14
	5	0
	7	10
	9	20
	12	6
	14	16
	17	2
	19	12
	21	22
	24	8
	26	18
	29	4
	31	14

V Serpentis

Mar.	2	2
	5	13
	9	0
	12	10
	15	21
	19	8
	22	19
	26	6
	29	17

RZ Draconis

Mar.	1	1
	2	3
	3	6
	4	8
	5	11
	6	13
	7	16
	8	18
	9	20
	10	23
	12	1
	13	4
	14	6
	15	9
	16	11
	17	14
	18	16
	19	18
	20	21
	21	23
	23	2
	24	4
	25	7
	26	9
	27	11
	28	14
	29	16
	30	19
	31	21

RX Herculis

Mar.	1	20
	2	18
	3	15
	4	12
	5	10

RX Herculis

	d	h
Mar.	6	7
	7	4
	8	2
	8	23
	9	20
	10	18
	11	15
	12	12
	13	10
	14	7
	15	4
	16	2
	16	23
	17	20
	18	18
	19	15
	20	12
	21	10
	22	7
	23	5
	24	2
	24	23
	25	21
	26	18
	27	15
	28	13
	29	10
	30	7
	31	5

SX Sagittarii

Mar.	2	10
	4	12
	6	14
	8	16
	10	18
	12	20
	14	22
	16	23
	19	1
	21	3
	23	5
	25	7
	27	9
	29	10
	31	12

RR Draconis

Mar.	2	20
	5	16
	8	12
	11	8
	14	4
	16	23
	19	19
	22	15
	25	11
	28	7
	31	3

U Scuti

Mar.	1	9
	2	8

U Scuti

	d	h
Mar.	3	7
	4	6
	5	5
	6	4
	7	2
	8	1
	9	0
	9	23
	10	22
	11	21
	12	20
	13	19
	14	18
	15	17
	16	16
	17	15
	18	14
	19	12
	20	11
	21	10
	22	9
	23	8
	24	7
	25	6
	26	5
	27	4
	28	3
	29	2
	30	1
	30	23
	31	22

RX Draconis

Mar.	2	12
	4	9
	6	7
	8	4
	10	2
	11	23
	13	21
	15	18
	17	16
	19	13
	21	11
	23	8
	25	5
	27	3
	29	0
	30	22

RV Lyræ

Mar.	4	8
	7	23
	11	13
	15	3
	18	18
	22	8
	25	23
	29	13

U Sagittae

Mar.	1	20

U Sagittae

	d	h
Mar.	5	5
	8	14
	11	23
	15	8
	18	17
	22	2
	25	12
	28	21

Z Vulpeculæ

Mar.	3	17
	8	18
	13	20
	18	21
	23	22
	28	23

SY Cygni

Mar.	4	1
	10	1
	16	1
	22	1
	28	1

WW Cygni

Mar.	2	1
	5	9
	8	17
	12	0
	15	8
	18	11
	21	23
	25	7
	28	14
	31	22

ZW Cygni

Mar.	2	11
	7	1
	11	15
	16	5
	20	18
	25	8
	29	22

UW Cygni

Mar.	3	11
	11	21
	20	8
	28	18

UW Cygni

Mar.	3	6
	6	17
	10	4
	13	14
	17	1
	20	12
	23	23
	27	10
	30	21

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini		RR Delphini		VV Cygni		VV Cygni		RT Lacertae	
d	h	d	h	d	h	d	h	d	h
Mar. 5	6	Mar. 27	7	Mar. 4	19	Mar. 24	0	Mar. 3	14
10	1	31	22	6	7	25	12	6	3
14	21	RR Vulpeculae		7	18	26	23	8	16
19	16	Mar. 5	19	9	6	28	11	11	5
24	11	10	20	10	17	29	22	13	18
29	7	15	21	12	5	31	10	16	7
RR Delphini		20	22	13	16			18	20
Mar. 4	8	26	0	15	4	UZ Cygni		21	9
8	28	30	25	16	15	Mar. 17	21	23	21
13	12	VV Cygni		18	2			26	10
18	3	Mar. 1	21	19	14	RT Lacertae		28	23
22	18	3	8	21	1	Mar. 1	2	31	12
				22	13				

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.		RX Aurigæ		Y Aurigæ		V Carinæ		R Crucis	
d	h	d	h	d	h	d	h	d	h
Mar. 21	19	(−4	0)	Mar. 23	20	(−2	4)	(−1	10)
SY Cassiop.		Mar. 3	2	27	16	Mar. 4	21	Mar. 6	20
Mar. 2	20	14	17	31	13	11	13	12	15
6	21	26	8	RZ Geminorum		18	6	18	11
11	00	SX Aurigae		(−1	7)	24	23	24	7
15	1	Mar. 1	12	Mar. 1	5	31	16	30	3
19	3	3	1	6	17	T Velorum		S Crucis	
23	5	4	14	12	5	(−1	10)	(−1	12)
27	6	6	2	17	18	Mar. 3	3	Mar. 5	15
31	8	7	15	23	6	7	19	10	8
RW Cassiop.		9	4	28	18	12	10	15	0
(−5	19)	10	17	RS Orionis		17	1	19	17
Mar. 3	22	12	5	(−2	0)	21	17	24	9
18	17	13	18	Mar. 3	12	26	8	29	2
SU Cassiop.		15	7	11	1	30	23	RZ Centauri	
(−0	22)	16	20	18	14	W Carinæ		Mar. 1	13
Mar. 2	11	18	9	26	4	(−1	0)	2	12
4	10	19	21	T Monoc.		Mar. 1	13	3	10
6	9	21	10	(−9	23)	5	22	4	9
8	7	22	23	Mar. 5	18	10	7	5	7
10	6	24	12	W Geminorum		14	16	6	6
12	5	26	0	(−2	2)	19	0	7	4
14	4	27	13	Mar. 5	7	23	9	8	3
16	2	29	2	13	5	27	18	9	1
18	1	30	15	21	3	S Muscæ		10	0
20	00	SY Aurigae		29	1	(−3	11)	10	23
21	23	Mar. 4	14	ξ Geminorum		Mar. 6	11	11	21
23	22	14	18	(−5	0)	16	3	12	20
25	20	24	21	Mar. 2	5	25	19	13	18
27	19	Y Aurigæ		12	8	T Crucis		14	17
29	18	(−0	18)	22	12	(−2	2)	15	15
31	17	Mar. 4	13	RU Camelop.		Mar. 6	18	16	14
SV Persei		8	9	(−9	12)	13	12	17	12
Mar. 1	22	12	6	Mar. 2	12	20	5	18	11
13	1	16	2	24	18	26	23	19	9
24	5	19	23					20	8

Maxima of Variable Stars of Short Period not of the Algol Type.-Con.

RZ Centauri

d	h
Mar. 21	6
22	5
23	3
24	2
25	0
25	23
26	21
27	20
28	18
29	17
30	15
31	14

W Virginis

d	h
(−8	5)
Mar. 4	20
22	3

V Centauri

d	h
(−1	11)
Mar. 2	22
8	10
13	22
19	10
24	22

R Triang. Austr.

d	h
(−1	0)
Mar. 2	1
5	10
8	19
12	5
15	4
18	24
22	9
25	18
29	4

S Triang. Austr.

d	h
(−2	2)
Mar. 4	2
10	9
16	17
23	1
29	9
4	16
11	0
17	8
23	16
29	23

S Normæ

d	h
(−4	10)
Mar. 4	10
14	4
23	22

RV Scorpii

d	h
(−1	10)
Mar. 5	3
11	4
17	6
23	7
29	9

RV Ophiuchi

Minimum

d	h
Mar. 1	6
4	23
8	15
12	8
16	0
19	17
23	9
27	2
30	18

X Sagittarii

d	h
(−2	22)
Mar. 5	5
12	5
19	5
26	5

Y Ophiuchi

d	h
(−6	5)
Mar. 12	2
29	5

W Sagittarii

d	h
(−3	0)
Mar. 6	8
13	23
22	13
29	3

Y Sagittarii

d	h
(−2	2)
Mar. 6	1
11	20
17	14
23	9
29	4

U Sagittarii

d	h
(−2	23)
Mar. 1	10
8	3
14	21
21	15
28	9

β Lyræ

d	h
(−3	7)
(−3	2)
Mar. 2	3
8	9
15	1
21	7
27	23

κ Pavonis

d	h
(−4	7)
Mar. 7	19
16	21
25	23

U Aquilæ

d	h
(−2	4)
Mar. 1	10
8	10
15	11
22	11
29	12

U Vulpeculæ

d	h
(−2	3)
Mar. 1	22
9	22
17	22
25	21

SU Cygni

d	h
(−1	7)
Mar. 1	23
5	19
9	16
13	12
17	8
21	4
25	1
28	21

η Aquilae

d	h
(−2	6)
Mar. 7	8
14	12
21	17
28	21

S Sagittae

d	h
(−3	10)
Mar. 2	2
10	11
18	21
27	6

X Vulpeculae

d	h
(−2	1)
Mar. 3	5
9	13
15	20
22	4
28	11

V Vulpeculae

Minimum

d	h
Mar. 23	9

X Cygni

d	h
(−6	19)
Mar. 13	3
29	12

T Vulpeculae

d	h
(−1	10)
Mar. 2	21
7	8
11	18
16	4
20	15
25	1
29	12

TX Cygni

d	h
Mar. 5	10
20	3

VY Cygni

d	h
(−2	14)
Mar. 5	14
13	11
21	7
29	4

VZ Cygni

d	h
(−1	1)
Mar. 3	24
8	21
13	17
18	14
23	11
28	7

Y Lacertae

d	h
(−1	10)
Mar. 5	2
9	9
13	17
18	0
22	8
26	16
30	24

δ Cephei

d	h
Mar. 7	7
11	13
16	22
22	7
27	16

Z Lacertae

d	h
Mar. 5	13
16	11
27	8

RR Lacertae

d	h
(−1	2)
Mar. 4	5
10	15
17	1
23	11
29	21

V Lacertae

d	h
(−1	16)
Mar. 3	14
8	13
13	13
18	13
23	12
28	12

X Lacertae

d	h
Mar. 4	5
9	16
15	3
20	13
26	00
31	11

SW Cassiop.

d	h
Mar. 1	18
7	4
12	15
18	1
23	12
28	20

RS Cassiop.

d	h
(−1	19)
Mar. 5	17
11	24
18	7
24	14
30	21

RY Cassiop.

d	h
(−7	10)
Mar. 7	18
19	21

Approximate Magnitudes of Variable Stars on Jan. 1, 1910.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	14.0*d*	Y Cephei	0	31.3	+79	48	13.0
T Androm.		17.2	+26	26	13.5*d*	U Cassiop.		40.8	+47	43	13.0*d*
T Cassiop.		17.8	+55	14	8.0 *i*	RW Androm.		41.9	+32	8	13.0*d*
R Androm.		18.8	+38	1	10.5*d*	V Androm.		44.6	+35	6	13.8*d*

Approximate Magnitudes of Variable Stars on Jan. 1, 1910—Con.

Name.	R. A. 1900.	Decl. 1900.	Magn.	Name.	R. A 1900	Decl. 1900	Magn.
	h m	° ′			h m	° ′	
RR Androm	0 45.9	+33 50	<13.8	RS Gemin.	6 55.2	+30 40	11.0
RV Cassiop.	47.1	+46 53	<13.5	R Gemin.	7 1.3	+22 52	9.5*d*
W Cassiop.	49.0	+58 1	10.0*d*	R Can. Min.	3.2	+10 11	8.5
Z Ceti	1 1.6	− 2 1	13.0	V Gemin.	17.6	+13 17	13.5
U Androm.	9.8	+40 11	<14	Z Puppis	28.3	−20 27	9.0*d*
S Piscium	12.4	+ 8 24	<13.5	S Can. Min.	27.3	+ 8 32	11.5
S Cassiop.	12.3	+72 5	9.0 *i*	T Can. Min.	28.4	+11 58	13
U Piscium	17.7	+12 21	13.8*d*	U Can. Min.	35.9	+ 8 37	13
R Piscium	25.5	+ 2 22	12.5 *i*	S Gemin.	37.0	+23 41	8.5
R Sculpt.	22.4	−33 4	7.5*d*	T Gemin.	43.3	+23 59	12.5
X Cassiop.	49.8	+58 46	11.0*d*	R Cancri	8 11.0	+12 2	10.0*d*
U Persei	53.0	+54 20	9.5*d*	V Cancri	16.0	+17 36	9.2 i
S Arietis	59.3	+12 3	10.0 *i*	S Pyxidis	9 0.7	−24 41	12.5*d*
R Arietis	2 10.4	+24 35	9.0 *i*	W Cancri	4.0	+25 39	8.5
W Androm.	11.2	+43 50	10.5*d*	R Carinae	29.7	−62 21	10.0*d*
Z Cephei	12.8	+81 13	11 *i*	X Hydrae	30.7	−14 15	12.5 *i*
o Ceti	14.3	− 3 26	7.5*d*	RR Hydrae	40.4	−23 34	13.2*d*
S Persei	15.7	+58 8	8.8 *i*	R Leonis	42.2	+11 54	8.8*d*
R Ceti	20.9	− 0 38	11.8 *i*	V Leonis	54.5	+21 44	9.5
RR Persei	21.7	+50 49	11.5 *i*	Y Hydrae	46.4	−22 33	7.0
U Ceti	28.9	−13 35	7.8 *i*	RR Carinae	54.8	−58 23	8.5*d*
RR Cephei	30.4	+80 42	9.5 *i*	R Urs. Maj.	10 37.6	+69 18	12.2 *i*
R Trianguli	31.0	+33 50	11.0*d*	V Hydrae	46.8	−20 43	8.8*d*
T Arietis	42.8	+17 6	10.0	W Leonis	48.4	+14 15	<13
W Persei	43.2	+56 34	10.0	S Leonis	11 5.7	+ 6 0	<13
U Arietis	3 5.5	+14 25	12 *i*	RX Virginis	59.6	− 5 13	8.2
X Ceti	14.3	− 1 26	10.2 *i*	R Comae	59.1	+19 20	13
Y Persei	20.9	+43 50	10.0	RW Virginis	12 2.1	− 6 12	7.0
R Persei	23.7	+35 20	9.0 *i*	T Virginis	9.5	− 5 29	13.0*d*
Nov. Per. 2	24.4	+43 34	12.5	SS Virginis	20.1	+ 1 19	7.2
S Fornacis	41.9	−24 42	9.0	T Can. Ven.	25.2	+32 3	9.4 *i*
U Eridani	46.2	−25 16	8.5	Y Virginis	28.7	− 3 52	11.0 *i*
T Eridani	51.0	−24 20	9.5*d*	U Centauri	28.0	−54 6	13.0*d*
W Eridani	4 7.3	−25 24	<13	T Urs. Maj.	31.8	+60 2	9.5 *i*
T Tauri	16.2	+19 18	13 *d*	R Virginis	33.4	+ 7 32	7.7 *i*
R Tauri	22.8	+ 9 56	<13	RS Urs. Maj.	34.4	+59 2	14.0
S Tauri	23.7	+ 9 44	<13	S Urs. Maj.	39.6	+61 38	8.5*d*
T Camelop.	30.4	+65 57	8.5 *i*	RU Virginis	42.2	+ 4 42	10.0*d*
RX Tauri	32.8	+ 8 9	<13	U Virginis	46.0	+ 6 6	8.5 *i*
X Camelop.	32.6	+74 56	8.0	RT Virginis	57.6	+ 5 43	8.3
V Tauri	46.2	+17 22	9.0 *i*	T Urs. Min.	13 32.6	+73 56	12.5*d*
R Orionis	53.6	+ 7 59	11.2*d*	R Can. Ven.	44.6	+40 2	8.5*d*
V Orionis	5 0.8	+ 3 58	9.8 *i*	U Urs. Min.	14 15.1	+67 15	9.8*d*
T Leporis	0.6	−22 2	9.5*d*	S Bootis	19.5	+54 16	10.5*d*
R Aurigae	9.2	+53 28	9.0 *i*	R Camelop.	25.1	+84 17	13.0*d*
S Aurigae	20.5	+34 4	9.2*d*	S Urs. Min.	15 33.4	+78 58	9.0 *i*
W Aurigae	20.1	+36 39	<13.5	RR Herculis	16 1.5	+50 46	8.6
S Camelop.	30.2	+68 45	10.0	W Coronae	11.8	+38 3	13.0
RR Tauri	33.3	+26 19	12.8	W Herculis	31.7	+37 32	11.5 *i*
U Aurigae	35.6	+31 59	8.8*d*	R Draconis	32.4	+66 58	12.2
U Orionis	49.9	+20 10	12.0*d*	T Draconis	17 54.8	+58 14	9.5 *i*
V Camelop.	49.4	+74 30	13.0	— Draconis	54.7	+58 13	11.5*d*
Z Aurigae	53.6	+53 18	9.5 *i*	V Draconis	56.3	+54 53	10.5*d*
X Aurigae	6 4.4	+50 15	10.5	T Herculis	18 5.3	+31 0	12.8
V Aurigae	16.5	+47 45	10.7	W Draconis	5.4	+65 56	13.0*d*
V Monoc.	17.7	− 2 9	11	W Lyrae	11.5	+36 38	<13
R Monoc.	33.7	+ 8 49	11·2	SV Herculis	22.3	+24 58	9.5*d*
S Lyncis	35.9	+58 0	<13	RY Lyrae	41.2	+34 34	12.2*d*
X Gemin.	40.7	+30 23	9.5 i	Z Lyrae	56.0	+34 49	10.5 *i*
Y Monoc.	51.3	+11 22	13.3*d*	RT Lyrae	57.8	+37 22	11.5 i
R Lyncis	53.0	+55 28	8.0 *i*	R Aquilae	19 1.6	+ 8 5	10.0*d*

Approximate Magnitudes of Variable Stars on Jan. 1, 1910—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
RS Lyrae	19	9.3	+33	15	13.8*d*	R Equulei	21	8.4	+12	23	13.5
RU Lyrae		9.1	+41	8	13.0*d*	T Cephei		8.2	+68	5	9.7*d*
U Draconis		9.9	+67	7	9.5 *i*	RR Aquarii		9.8	− 3	19	13.0
TZ Cygni		13.4	+50	0	10.6	X Pegasi		16.3	+14	2	12 5 *i*
U Lyrae		16.6	+37	42	10.4 *i*	S Cephei		36.5	+78	10	9.5*d*
TY Cygni		29.8	+28	6	13.2*d*	RU Cygni		37.3	+53	52	8.0 *i*
RT Aquilae		33.3	+11	30	10.7 *i*	RR Pegasi		40.0	+24	33	9.5
R Cygni		34.1	+49	58	10.0*d*	V Pegasi		56.0	+ 5	38	14.0
RV Aquilae		35.9	+ 9	42	14.0*d*	RT Pegasi		59.8	+34	38	11.6*d*
RT Cygni		40.8	+48	32	8.0 *i*	T Pegasi	22	4.0	+12	3	12.0 *i*
TU Cygni		43.3	+48	49	10.0 *i*	Y Pegasi		6.8	+13	52	9.0 *i*
X Aquilae		46.5	+ 4	13	13.0*d*	RS Pegasi		7.4	+14	4	<13
χ Cygni		46.7	+32	40	12.5*d*	RV Pegasi		21.0	+29	58	9.5
Z Cygni		58.6	+49	46	11.5 *i*	S Lacertae		24.6	+39	48	11.5*d*
S Cygni	20	3.4	+57	42	12.5*d*	R Lacertae		38.8	+41	51	12.5 *i*
RU Aquilae		8.0	+12	42	11.0*d*	S Aquarii		51.8	−20	53	10.8*d*
Z Aquilae		9.8	− 6	27	9.0 *i*	RW Pegasi		59.2	+14	46	13.0
RS Cygni		9.8	+38	28	8.0*d*	R Pegasi	23	1.6	+10	0	11.0*d*
R Delphini		10.1	+ 8	47	8.0	V Cassiop.		7.4	+59	8	12.5
SX Cygni		11.6	+30	46	12.5*d*	W Pegasi		14.8	+25	44	9.8*d*
U Cygni		16.5	+47	35	9.5*d*	S Pegasi		15.5	+ 8	22	10.0 *i*
RW Cygni		25.2	+39	39	9.5	Z Androm.		28.8	+48	16	10.5
Z Delphini		28.1	+17	7	12.5*d*	ST Androm.		33.8	+35	13	8.5
S Delphini		38.5	+16	44	9.0 *i*	R Aquarii		38.6	−15	50	10.3
V Cygni		38.1	+47	47	11.0 *i*	Z Cassiop.		39.7	+56	2	11.8*d*
Y Aquarii		39.2	− 5	12	9.5 *i*	Z Aquarii		47.1	−16	25	7.0
W Aquarii		41.2	− 4	27	11.5*d*	RR Cassiop.		50.7	+53	8	9.5 *i*
V Aquarii		41.8	+ 2	4	10.0 *i*	R Phoenicis		51.3	+50	21	11.5*d*
T Aquarii		44.7	− 5	31	12.5	V Ceti		52.8	− 9	31	14
RZ Cygni		48.5	+46	59	9.5 *i*	R Cassiop.		53.3	+50	50	6.5 *i*
X Delphini		50.3	+17	16	13.8*d*	Z Pegasi		55.0	+25	21	9.5*d*
R Vulpeculae		59.9	+23	26	9.0*d*	W Ceti		57.0	−15	14	11.5*d*
TW Cygni	21	1.8	+29	0	10.0 *i*	Y Cassiop.		58.2	+55	7	<14
X Cephei		3.6	+82	40	9.5 *i*						

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Mt. Holyoke, Eadie and Harvard Observatories including the South African Station of the latter.

Variable *u* Herculis.—In *A. N.* 4379 Mr. Felix de Roy gives the results of observation of a minimum of this variable on Nov. 9. The time of minimum agrees within 0.03 days with the computed time according to the elements given on page 654, December number of POPULAR ASTRONOMY, showing that Enebo's elements there given are quite exact.

Dr. Schlesinger, director of the Allegheny observatory calls attention to the following erroneous statement which we made in the December note on this star: "The entire light change requires 4.10204 days." This should read: "The entire light change requires 2.05102 days."

Variable 158.1908 Draconis.—In *A. N.* Mr. J. Voûter of Leiden gives as approximate elements of this variable

$$\text{Max.} = 2418410 + 87^{d}\ \text{E.}$$

Amplitude of variation $8^{m}.9 - 9^{m}.3$. Maximum to minimum 28 days.

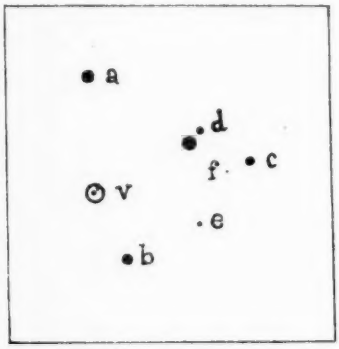
Algol Variable 21.1909 Andromedae.—In *A. N.* 4375 Mr. A. Kopff of the Heidelberg observatory gives observations of the Algol type variable 21.1909 which determine the following minima :

1909 Aug.	23.71	Sept. 17.43	Königstuhl mean time
Sept.	9.20	Oct. 20.40	Königstuhl mean time

From these the period appears to be 4.121 days, and the following formula for minima may be used :

Min. = 1909 Oct. 20.38 Gr. m. t. + 4.121 E.

The light curve at minimum seems to be unsymmetrical the light falling off more rapidly than it rises.



VICINITY OF 21.1909 ANDROMEDAE.

In *A. N.* 4375 Mr. J. Van der Bilt of Utrecht gives four minima of the same star on the following dates :

E	1909	J. D. (Gr. m. t.)	Obs.
−9	Sept. 17	2418567.4	4
0	Oct. 24	8604.539	15
6	Nov. 18	8629.271	9
7	Nov. 22	8633.392	8

He obtains the elements

Min. = 2418604.539 Gr. m. t. + $4^d.122$ E.

There will be minima Mar. 1 8^h, 5 11^h, 9 13^h, 13 16^h, and 17 19^h. The position of the star for 1900.0 is

$\alpha = 23^h\ 58^m\ 10^s$ $\quad \delta = +32°\ 17'.3$.

A Probable Variable 44.1909 Ursae Majoris.—In *A. N.* 4375 Professor W. Ceraski calls attention to a star of about 10th magnitude, found on a plate taken March 23, 1909, $10^h\ 6^m$–$12^h\ 6^m$ Moscow mean time, which is absent from twenty-four photographs of the same region taken between 1906 and 1909. Its position for 1900 is

$\alpha = 8^h\ 29^m\ 26^s$ $\quad \delta = +53°\ 50'$.

Variable DM 34°4598.—In *A. J.* 605 Mr. Paul S. Yendell calls attention to the star DM 34°4598, which is given as $9^m.2$ in the DM but which Mr.

Yendell found on Nov. 30, 1909 to be invisible with a 4¼-inch telescope and on the nights of December 5, 6, 8, 9, 10, and 11 to be below magnitude 10. Its position for 1855 is

$$\alpha = 21^h\ 59^m\ 27^s.7 \qquad \delta = +34^\circ\ 13'.0.$$

Variable DM 34°4600.—In *A. J.* 607 Mr. Paul S. Yendell announces as variable the star DM 34°4600. The DM magnitude is 9.2 but Mr. Yendell finds it to range between $8^m.9$ and $9^m.6$ in a period of about six days. Its position for 1855 is

$$\alpha = 22^h\ 00^m\ 9^s.2 \qquad \delta = +34^\circ\ 44'.8$$

It has been used by Mr. Yendell as a comparison star for the variable 162.1907 Pegasi.

GENERAL NOTES.

A New Observatory at Moscow. From the *Astronomische Nachrichten* No. 4377 we learn that a new astronomical observatory was founded at Moscow, Russia, by M. Archinoff. Its instrument is an excellent refractor mounted by G. Heyde with an objective of 130 mm. by Zeiss. An astrograph with a photographic "Tessar" objective by Zeiss of 87 mm. aperture is designed for photographing comets. The address is: Moscow, Bolchaya Ordinka, masion Archinoff.

William Tyler Olcott is the name of the author of "In Starland with a Three-Inch Telescope" which was reviewed in the January number. We apologize for the serious misprint in his name in the above mentioned review, which made him recognize himself with difficulty!

Schurig's Himmels-Atlas to which Miss Furness, director of the observatory of Vassar College, recently called attention may be obtained postpaid, for 80 cents of G. E. Stechert and Comany, 129 West 20th Street, New York City.

Saw Halley's Comet in 1835. At the suggestion of Professor Frederic Campbell of the Brooklyn Institute, I am writing the following letter for publication in your magazine, if you so desire.

Dr. Wm. G. Todd.

The writer is one of the very few people living to-day, who saw Halley's comet when it appeared in 1835. I was born at Fairfield, Vermont, September 27, 1821, and so was then about fourteen years of age. When the comet was first seen, it appeared in the western sky, right after sunset, its head toward the north and tail toward the south, about horizontal and considerably above the horizon and quite a distance south of the Sun. It could be plainly seen directly after sunset every day, and was visible for a long time, perhaps a month or more. It appeared very near to us at that time and very large and was plain to be seen in the heavens before the stars showed up, but I understand the comet will not be so close to us this year as in 1835. The tail of the comet was broad and not so very long, not to be compared as to length with the comet of 1843, the tail of which was very long and extended clear across the southern sky.

I have since learned, though I was in ignorance of the fact at that time, that after the perihelion, this comet was seen in the east, in the early morning hours and was visible for quite a period of time.

I became interested in astronomy at that time and have owned a telescope ever since. I have now a three-inch telescope.

I am in excellent health, my faculties all in good condition and I expect, when this comet appears in the next two or three months, to be able to see it with the naked eye. I expect it will take its course as previously, appearing in the western sky in just about the same position, but as to what time of day it will make its appearance, I do not know. However, it may be diverted from its previous course somewhat by the attraction of Jupiter and the other planets.

Trusting this information may be of interest to you and the readers of your publication, I am,

WM. G. TODD.

Chicago, Ill.

Resume of Sun-Spot Observations, 1909.

Month	No. of Obs.	N. of Equator No. Groups	N. of Equator Av. Lat.	S. of Equator No. Groups	S. of Equator Av. Lat.	Av. No. at each Ob.	New Groups
			°		°		
January	15	7	+5.6	5	−16.4	2.87	12
February	16	5	4.2	9	16.7	2.69	10
March	20	5	6.8	8	15.4	2.80	9
April	15	4	5.4	5	13.4	1.87	6
May	20	2	5.0	5	16.5	2.05	6
June (1-16)	8	0	—	4	9.9	1.38	3
October	23	6	4.4	11	11.2	3.04	17
November	15	6	8.8	12	11.9	3.40	16
December	12	5	+7.4	9	−10.4	2.92	8

Total number of observations	144
Total number of groups	87
Average number at each observation	2.69
Average latitude of groups north of equator	+ 6°.1
Average latitude of groups south of equator	−13 .3

A group appearing upon the eastern limb was counted as "new" although it might have been observed at the previous presentation.

No spots were seen on February 8 and 9, April 9, 10, 12 and 13, December 10 and 11.

The method of observation was the same as that used in previous years, the image of the Sun formed by an eight-inch equatorial refractor being projected upon Thomson's disks, from which the approximate latitude of the spots and their distance from the Sun's center was read directly.

The observations of the first half of the year were made by Miss Anna L. Oathout, of the last three monshs by Miss Margo L. Lewis, assistants in the observatory.

ANNE SEWELL YOUNG.

Mount Holyoke College.

The Cemetery of the Gods.

Thou vast illimitable expanse of blue,
Where stars and meteors whirl in endless space;
Thou cloth of gold with nebulae for lace,
Inexplicable delight to every mortal view,
There is no hallowed ground on Earth, so true
Receptacle for great of human race;
The modern champions of worth and grace,
Have no such mausoleum, old or new.

The gods and heroes of the storied past,
Have niches in these corridors of light
Those worshipped for transcendent gifts and might
Are honored still in starry realms so vast.
No common clay has sepulchre so fine,
The gods are dead, but they forever shine.

Spokane, Washington. JOHN F. DAVIES.

Erratum. On page 71 this issue the reference in line 12 should read to Plate VI.